The Bohlen-Pierce Scale: Continuing Research

Elaine Walker - Final Project in Advanced Acoustics, NYU, Spring 2001

The purpose of this project was to conduct a study on the perception of scales and chord progressions in the Bohlen-Pierce Scale. The version of the Bohlen-Pierce Scale I used in these experiments is an equal-tempered scale based on the 13^{th} root of 3, which gives 13 equal steps spanning the "tritave" (an octave and a fifth). This scale has been shown to have perceptible properties such as consonant and dissonant chords, and a rich structure that is comparable in complexity to the 12 tone equal tempered scale, but completely different in detail. This study included a set of listening examples and data sheets for the subjects to fill out. For the test subjects, I primarily chose trained musicians, so that they would understand the terminology like "major", "minor" or "cadence" that were prevalent in the questions relating to the listening examples. In general, a much different set of questions and experiments would need to be written for test subjects with no musical training.

Figure 1: Bohlen in 1973, tinkering with the transcription of a Christmas carol into his "13-Step Scale" (BP)

The Bohlen-Pierce Scale was designed by Heinz Bohlen, a microwave electronics and communications engineer, in the early 1970's in just tuning. He discovered its suitability to be turned into an equally tempered scale with a minimal defect just days after inventing the tuning. About six years later, another microwave electronics and communications engineer, John R. Pierce ("Father of the Communication Satellite" and creator of the "Pierce (electron) gun") discovered the same scale again, also proposing that it be used in the equal tempered form. Together with Max V. Mathews and others, he published his discovery in 1984. Learning later about Bohlen's earlier publication, the authors dubbed the new scale the "Bohlen-Pierce scale" and the name stuck.

On the average, the equal tempered Bohlen-pierce scale approximates the just Bohlen-Pierce scale twice as well as the twelve-tone equal-tempered scale approximates the diatonic scale. The basic idea leading to BP is simple. It is generally accepted that the major triad in our standard twelve tone tuning, 6/5/4, possesses almost ideal harmonic properties, and that the interval with the highest consonance is the octave (2/1). Another triad of high harmonic value is 7/5/3, although it is entirely incompatible with the traditional twelve tone scale. It is compatible however, with a scale based on the "tritave" (3/1). The tritave offers itself as an alternate frame interval, with a consonance grade second only to the octave.

For the purpose of understanding the Bohlen-Pierce scale, we can go through some simple steps to derive the scale. Starting with the values of our new triad 7/5/3, 1/1 is the base tone, then 5/3 and 7/3, and finally 3/1 is the top tone. Now, if the triad is played so that it ends with the top tone, it then leads to two new tones: 9/7 and 15/7. In doing this, another triad has been created. Taking 5/3 as a starting point, 7/3 and 3/1 form a triad 9/7/5 with it. With the base tone of the scale as support, this generates 7/5 and 9/5 as new members of our scale. The following table shows the results:

Result of first phase	Result of 2nd phase	Result of 3rd phase	Relation to previous tone
1/1		1/1	-
	9/7		9/7 = 1.2857
		7/5	49/45 = 1.0889
5/3			25/21 = 1.1905
		9/5	27/25 = 1.0800
	15/7		25/21 = 1.1905
7/3			49/45 = 1.0889
3/1	3/1		9/7 = 1.2857

Figure 2: Harmonic Framework of the Bohlen-Pierce Scale

This is the basic harmonic framework of the BP scale. Calculating the distances between the tones reveals three different categories. There is a small one (either 1.0800 or 1.0889), a medium one (1.1905), and a large one (1.2857). It soon becomes obvious that the medium one is about twice the small ones, and that the large one is the sum of the medium one and a small one (1.0800 x 1.1905 = 1.2857). Thus the relation small: medium: large is about 1:2:3. The "small" and "medium" distances can be considered “semitones” and “whole tones”. Filling each of the whole tone gaps in turn with semitones would produce a chromatic scale. Respecting the "symmetry axis" between 5/3 and 9/5 that rules the harmonic framework in the previous table, the rest of the gaps were filled in, arriving at a scale with thirteen steps:

Step no.	Tone (relation to base)	Relation to previous step
0	1/1	-
1	27/25	27/25
2	25/21	625/567
3	9/7	27/25
4	7/5	49/45
5	75/49	375/343
6	5/3	49/45
7	9/5	27/25
8	49/25	49/45
9	15/7	375/343
10	7/3	49/45
11	63/25	27/25
12	25/9	625/567
13	3/1	27/25

Figure 3: Frequency Ratios of the Bohlen-Pierce Scale

John Pierce proposed an equal-tempered scale step of the 13th root of 3, which gives 13 equal steps spanning the tritave. Remarkably, 13 steps are sufficient to create an equally tempered scale that deviates less from the BP scales in just tuning than the equally tempered western scale from its just relatives. A half tone step in this scale equals the thirteenth route of three (or 146.3 cent). The following table shows the cent values for the BP chromatic scale in equal temperament compared to that in just tuning:

Step no.	Equal temperament [cent]	Just tuning [cent]	Deviation (defect) [cent]
0	0	0	0
1	146	133	+ 13
2	293	302	- 9
3	439	435	+ 4
4	585	583	+ 2
5	732	737	- 5
6	878	884	- 6
7	1024	1018	+ 6
8	1170	1165	+ 5
9	1317	1319	- 2
10	1463	1467	- 4
11	1609	1600	+ 9
12	1756	1769	- 13
13	1902	1902	0

Figure 4: Equal Tempered Bohlen-Pierce Scale

Previous Research

Other experiments have been performed in the late 80's by Max Mathews and John Pierce with the Bohlen-Pierce Scales that also included non-musicians. They intended to use the Bohlen-Pierce Scales as (1) a vehicle to study long-term learning of high-level musical concepts, and (2) as an example of the creation of a new musical language with a rich and partly specified harmonic structure. I will be primarily focusing on the latter. It is interesting to note, however, that existing work with the Bohlen-Pierce Scales shows both the possibilities and limitations of our present psychoacoustic knowledge applied to musical scales.

In further experiments that they proposed, test subjects would be given extensive ear training until they could reliably transcribe music played in the Bohlen-Pierce Scale. I do not believe the experiments involving extensive ear training were carried out to any great degree. Part of the reason, which Max Mathews has told me himself, is that there has not been enough music actually written in this tuning for any large amount of ear training to be possible. Through their research, and the research of others, they did formalize scales, modes, chords, and notation for the Bohlen-Pierce Scale, which I will outline below, and will be using in my listening experiments.

A portion of their research they felt was incomplete was the question of whether there were "diatonic" modes of the Bohlen-Pierce Scale that carry tonal potential. The following table shows the diatonic BP modes that so far have been the subject of some investigation. These, plus two additional modes that I came up with, were included in my listening examples:

Mode =>	Dur I	Dur II	Moll I (Delta)	Moll II (Pierce)	Gamma	Harmonic	Lambda
1/1	X	X	X	X	X	X	X
27/25	X			X	X	X	
25/21		X	X				X
9/7	X	X	X	X	X	X	X
7/5	X	X		X	X	X	X
75/49			X				
5/3	X	X	X	X	X	X	X
9/5	X	X	X	X	X	X	X
49/25	X				X		
15/7		X	X	X		X	X
7/3	X	X	X	X	X	X	X
63/25	X	X				X	
25/9			X	X	X		X
3/1	X	X	X	X	X	X	X

Figure 5: Previously Evaluated Modes of the Bohlen-Pierce Scale

An interesting yet troublesome question in their research regarded the degree to which Bohlen-Pierce scale chord inversions can be perceived. Since this scale is not based on octaves, and contains no 2/1 ratios, there are no two pitches with the same pitch class in the Bohlen-Pierce scale, and thus, the concept of chord inversions would be quite different. In their inversion experiments,l two groups of subjects, one musically trained, athe other without special musical training, judged a series of chords and their inversions. The results were summarized as follows:

a) Neither group of subjects found Bohlen-Pierce Scale chords and their inversions to be similar. Instead their similarity ratings were correlated to the average pitch of the chords.

b) The musically trained subjects rated traditional chords and their inversions as similar. The musically untrained subjects DID NOT. Instead their similarity ratings were again correlated with average pitch of the chords.

These results are consistent with the hypothesis that these similarity judgments are learned and that with training, subjects might judge Bohlen-Pierce Scale chords and music quite differently. I do not believe there was ever enough formal training for this hypothesis to be taken to a final conclusion. Since I will not have time to formally train subjects, I will not be testing this hypothesis further at this time.

Several experiments were not formally executed because preliminary informal listening tests indicated that they were unlikely to yield interesting results. These include identification of key and judgement of modulation, and judgement of perceived finality of cadences. By “finality” I am referring to the sense that a chord progression has a sense of closure, or a sense of coming to a resting point, such as the cadence of IV-V-I in the 12 tone tuning. According to Max Mathews and John Pierce, no Bohlen-Pierce scale cadences have been found which give much of a sense of finality. However, I beg to differ, since I have heard at least two pieces written in this tuning that give me a sense of cadence and finality in at least some of the chord progressions. To me, from a composer’s standpoint, this is one of the most important questions that could be answered regarding an unfamiliar tuning. I chose not to execute any experiments regarding key, since I am using the equal-tempered version of the Bohlen-Pierce Scale, but did focus a small amount on modulation perception. Max Mathews and John Pierce used several short example compositions that were made in the Bohlen-Pierce scale, which involved key changes and modulations. Although one could believe that they key change could be heard, the perception was apparently so tenuous that no systematic studies were done. Again, I feel that modulation perception is an extremely important factor in musical composition, and that further experiments are strongly justified.

As I stated earlier, Max Mathews and John Pierce conducted their experiments with the Bohlen-Pierce Scale partly as a study of long-term learning of high-level musical concepts. One of the most difficult aspects in the domain of language learning is separating the components of a language which are learned from those which are an inherent part of the structure of the organism. Because languages, including the twelve tone standard tuning system, are learned at such young ages, experiments are difficult to run. They believe the Bohlen-Pierce scales are unique stimuli with which to study learning of these higher-level concepts because subjects exist that have no previous exposure to the scales. In that regard, my experiments can be used in the future as a small subset of a larger study on the learning of high-level musical concepts.

Previously Determined Chords, Modes, Notation and Key Signatures

I originally wanted to base this study on previous scales and chords that John Pierce and Max Mathews have already worked out, because what I had seen so far, had been logically worked out and appeared to me to be musically sound. However, it seems that all they have published to my knowledge are the 7 modes (shown in Figure 4 above), and the two main triads that the tuning was originally derived from. The two main triads are referred to as the “Wide Triad” (3:5:7, for example CGA) and the “Narrow Triad” (5:7:9, for example CFH). Bohlen had originally named 3:5:7 the "major triad" and 5:7:9 the "minor triad". It was decided, however, that these names unavoidably triggered the expectation that there should exist a BP tonality fully parallel to that of the traditional Western scale. To prevent people from jumping to conclusions in this respect, "wide" and "narrow" triad have been the accepted working titles.

For reference, below is an example of Bohlen-Pierce notation. In this case, the upper “c” would sound an octave and a fifth higher in pitch than the lower “c”. This interval is referred to by John Pierce as a tritave, and the notes in between (146 cents apart in the equal tempered verion) make up the Bohlen-Pierce Scale. The notated scale below is the C-Lambda scale, which is the last mode in the chart in figure 5 above. Key signatures for the 12 different Lambda keys follow.

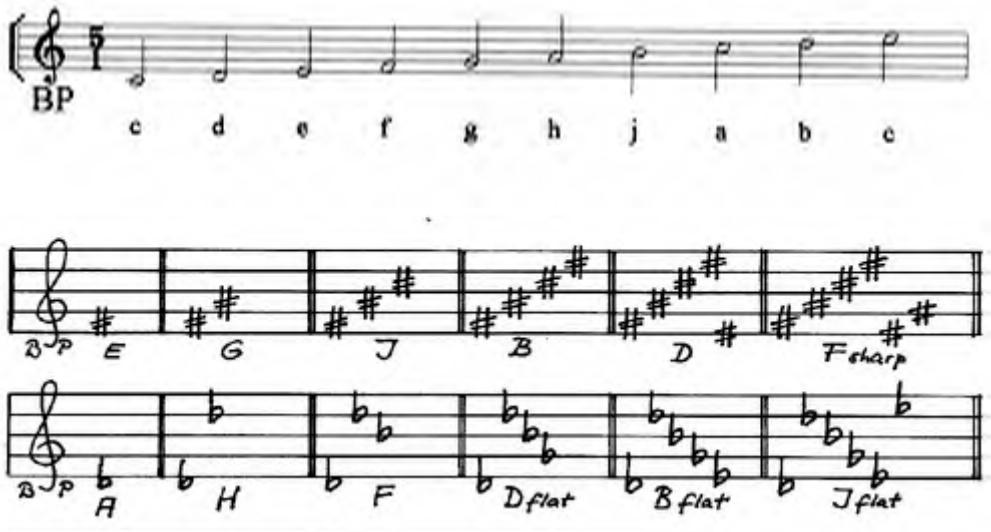

Figure 6: Notated C-Lambda scale, and the 12 Lambda Key Signatures

The above notation was downloaded from the Bohlen-Pierce web site. I can only assume that it was decided not to use the letter **i**, simply because it might be confused with Roman Numerals such as I or IV etc. When I was taking a closer look at the notation, I realized I hadn't referenced which mode it was taken from, and I wasn't sure if anyone had settled on which mode to use as the main diatonic mode (Like C-Major, for instance). I had trouble finding the website again, and so proceeded to figure it out on my own. Starting with the first mode in Figure 5, assuming that may be the main tonic mode, then proceeding next to try the mode named "Moll II (Pierce)", I finally made my way to the Lambda mode which fit perfectly with these key signatures. Indeed, on later stumbling into the website again, it was the notation for the C-Lambda mode.

I took note that the Lambda mode was one of the best choices for the main tonic mode because it includes all five of the scale intervals needed to make up the "wide" and "narrow" triads. These scale intervals are highlighted in red in figure 7 below, and the original seven modes are highlighted in dark red in the left column. As we will see later on, when we review my test results, the Lambda mode was one of the two modes that rated the highest among the 9 test subjects as to which was their "favorite"mode. That may or may not be a coincidence, taking into account the high amount of noise in the test sheet answers. In other words, the final tally did not lean strongly in any one direction.

Two New Modes and a New Order

I developed two additional modes, for reasons I will go over a little later, during my discussion of Bohlen-Pierce chords. I classified these modes as "Walker (Pierce II)" and "Walker (Delta II)", so entitled because they most closely resembled the "Moll II (Pierce)" and "Moll I (Delta)" modes. As it turns out, the "Walker (Pierce II)" mode was the other one of the two top-most rating modes from my listening tests. Again, because the opinions on the modes did not lean strongly in any one direction, I would suggest taking this particular result with a grain of salt.

Using Lambda as the reference point, since it seemed to be the diatonic mode of choice in the earlier studies of this tuning, and also happened to be one of the favorites among my own test subjects, I put the modes in a logical "order". I was thinking along the same lines as Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolean and Locrian, where each mode can be played on all white keys, with each successive scale having its root on the next available white key. Thinking of the scale degrees in the Lambda mode as the "white notes" (compared to the white notes in C Major on a piano keyboard) I cycled through the scale degrees and listed each mode I could find that fit the pattern of "whole" and "half" steps. I would assume that someone had done this before, during previous research in an attempt to order things, but I could not find a list of modes in any such order. For instance, the modes in figure 5 above don't seem to be in any particular logical order. I labeled each mode as "Diatonic" in the right column if they contained the five scale degrees of the two main triads (all highlighted in red).

Mode	The "white" notes (" | " represents "whole" steps)													
	1/1				7/5		5/3	9/5			7/3			←Triad Intervals
Lambda	C	|	D	E	F	|	G	H	|	J	A	|	B	C	Diatonic
* ?	D	E	F	|	G	H	|	J	A	|	B	C	|	D	
Moll II (Pierce)	E	F	|	G	H	|	J	A	|	B	C	|	D	E	Diatonic
* Walker (Pierce II)	F	|	G	H	|	J	A	|	B	C	|	D	E	F	
Harmonic	G	H	|	J	A	|	B	C	|	D	E	F	|	G	Diatonic
* Walker (Delta II)	H	|	J	A	|	B	C	|	D	E	F	|	G	H	
Dur I	J	A	|	B	C	|	D	E	F	|	G	H	|	J	Diatonic
Moll I (Delta)	A	|	B	C	|	D	E	F	|	G	H	|	J	A	
* ?	B	C	|	D	E	F	|	G	H	|	J	A	|	B	
Other Modes	These include accidentals (" | " represents "whole" steps)													
Dur II	C	|	D	E	F	|	G	H	|	J	A	Bb	|	C	Diatonic
Gamma	C	Db	|	E	F	|	G	H	Jb	|	A	|	B	C	Diatonic

Figure 7: Organization and Evaluation of the Modes

As you attempt to make sense out of the above chart, keep in mind that the scale 1/2 steps of the Bohlen-Pierce Scale, in reference to the C-Lambda mode, are:

C, Db, D, E, F, Gb, G, H, Jb, J, A, Bb, B, C

I had noticed that there were four gaps in my chart, notated with a *, where none of the original modes seemed to fit. Miraculously, the two modes I had come up with fit into two of the four empty slots. In brief, I had come up with these scales previously because I found that they contained more notes that corresponded to the chord progressions I came up with purely by ear, instead of fashioning them from just the two main triads and inversions. However, I did not have high hopes for them since they were each missing at least two of the main triad scale degrees. At least now I have found a home for my new modes. Of course, if anyone were ever to recognize this, I would be quite honored to share a mode name with John R. Pierce!

Physical Keyboard Layouts

If Lambda were indeed chosen to be the reference diatonic scale of choice, I can imagine a Bohlen-Pierce Scale keyboard fashioned as in my drawing below. It is different than the keyboard layout that Bohlen fashioned in 1972, (see figure 9 below) however, I believe he may have been referencing a different diatonic mode, and perhaps not even the equal tempered version of the scale. This design appears to me to be the simplest solution, however, I am not sure how reasonable it would be to actually perform on this keyboard. However, because of the fact that each interval is larger than a 12 tone 1/2 step, it might not be a negative thing that the black notes are a little farther apart, since the actual physical interval distance might be less on average. At any rate, for now this can suffice as a visual reference for those who may want to relate this tuning to a keyboard layout. Looking at figure 8, imagine that from C to the C above it, an interval would be heard that sounds like what we know as an "Octave and a Fifth", or three times the frequency. This is what John Pierce has called the "tritave" and it is divided, as we can see, into 13 equal steps.

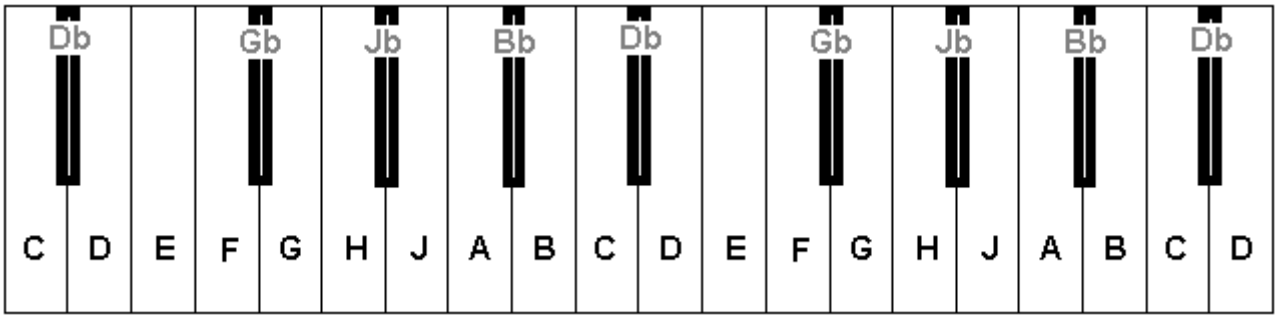

Figure 8: Elaine's Proposed Keyboard Layout for Bohlen-Pierce Scale, Referencing the C-Lambda Mode

Figure 9: 1st Bohlen-Pierce Scale Instrument Built by Heinz Bohlen in 1972

New Chord Progressions Created "by Ear" for the Listening Test

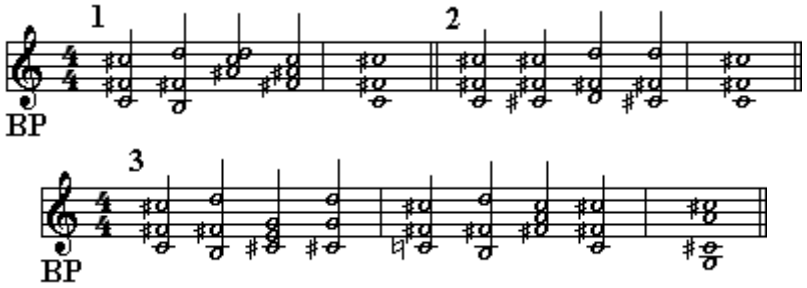

Figure 10: Three Chord Progressions in Bohlen-Pierce Notation

I came up with the above three chord progressions by ear, attempting to create progressions that sounded similar to I - IV - V - I and other familiar progressions. These progressions are also repeated in the "piano scroll" notation below (in figure 11), along with the other five progressions I sequenced for the listening test. I purposefully used the most consonant sounding intervals I could, and tried very hard to make them sound like the did indeed have harmonic movement, either resolving to the tonic, or undoubtedly landing on a new chord that would have a strong feeling of needing to be resolved. I personally feel that some of these progressions sound "cheesy" and others sound "exotic", in the same respect that a vast variety of emotion and content can be accomplished with 12 tone chord progressions and other viable tunings that are rich in functional harmonic content.

Below each of the eight chord progressions depicted in the piano scroll notations that follow, is a "12 tone" chord analysis done by a musician friend named Chris Child, who has a particularly acute ear. The roman numerals are referring to the "closest sounding 12 tone chord" that he could hear strictly by ear, and with a small amount of help doodling on a piano keyboard. These aren't necessarily the physically closest notes with respect to actual harmonic frequencies, but nevertheless, the closest "sounding" chords. In other words, Chris got the "feeling" of these 12 tone chords when listening to these Bohlen-Pierce Scale progressions. Chris was one of 9 test subjects that spent a little over an hour listening to these examples and filling in their test sheets. I will review his comments in this section, next to his analyses, since his comments were the ones that most closely resembles my personal opinions. In the next section of this paper I will talk more about the actual listening tests that took place, review the results of all the test subjects together, and attempt to come to some conclusions.

P-B Chord Progressions with 12 Tone Harmonic Analysis Relationships

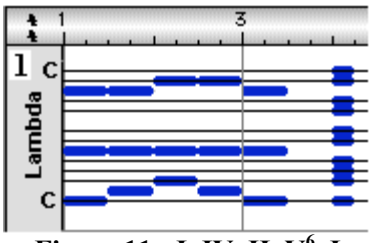

Figure 11: I, IV, II, V^6, I

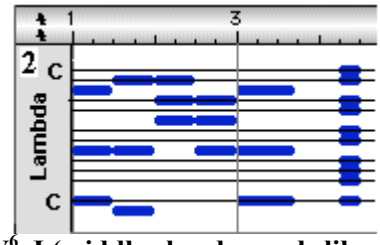

Figure 12: I, IV^6, I (middle chord sounds like a "pivot" chord)

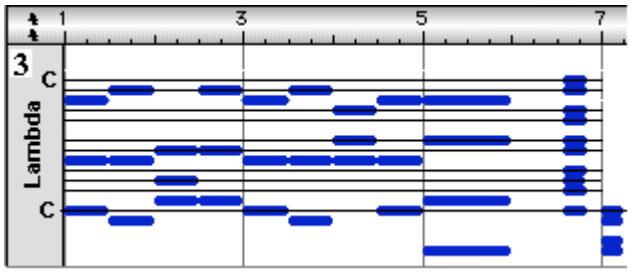

Figure 13: I, IV, VI(?), IV, I, IV, V, I, #IV

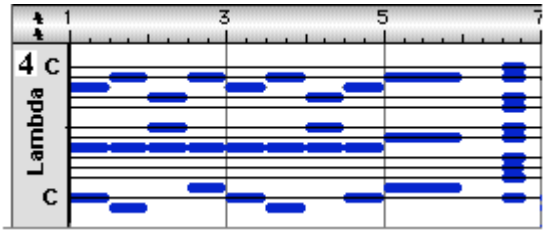

Figure 14: I, IV, ?, ?, I, IV, V, I, $^{\#}$IV

Chris proceeded to label the very first chord progression, which is rather short, as "beautiful, ethereal, heavenly". In the second progression, he only got a very weak sense of a IV^6 chord, and described it simply as a "pivot" chord. He got a similar feeling with the VI chord in example #3, and describes these chords as "the microtonal chords". He had a hard time making out the third chord in example #4, but described this progression as "very nice - same as previous comments" (haunting, ethereal, etc).

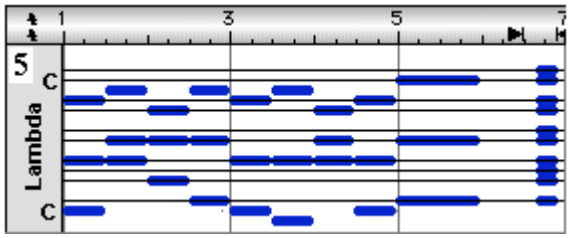

Figure 15: I, IV, V, IV, I, IV, V, I, VII^{o}/IV

Chris labeled this chord progression as "awesome". Perhaps he was impressed by the last chord. He felt (and I agree) that it sounds as if it will be leading into what would sound like a 12-tone "IV chord", and that the last chord is the diminished V^7 chord of the IV chord.

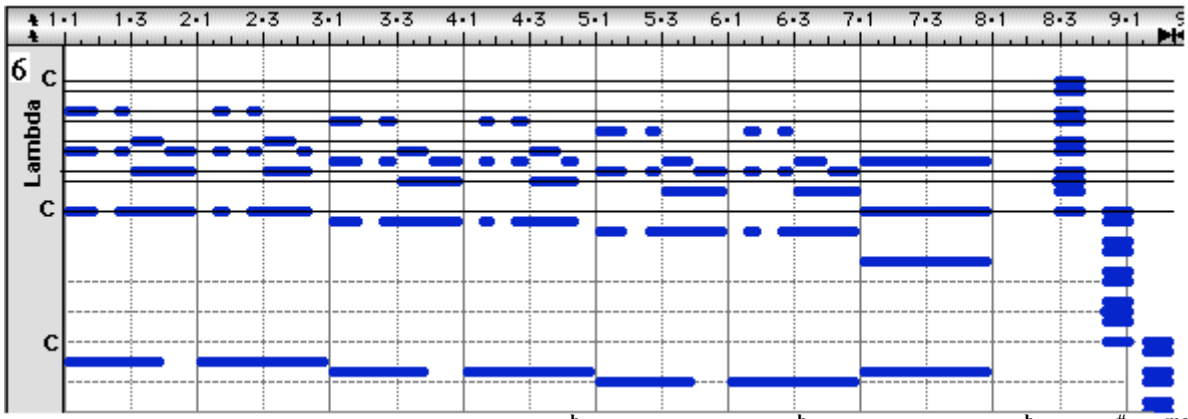

Figure 16: Going down by B-P "1/2 steps"; I, ^{b}VI, V down→ I, ^{b}VI, V down→ I, ^{b}VI, V, $^{\#}$IV ^{maj}

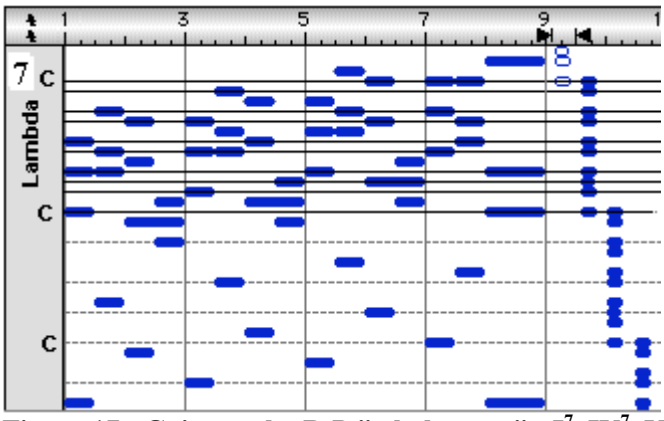

Figure 17: Going up by B-P "whole steps"; I^7, IV^7, VII^7, VII^7 up→ I^7, IV^7, VII^7, VII^7 up→ I^7, IV^7, VII^7, VII^7 up→ I, VI^{aug}, III

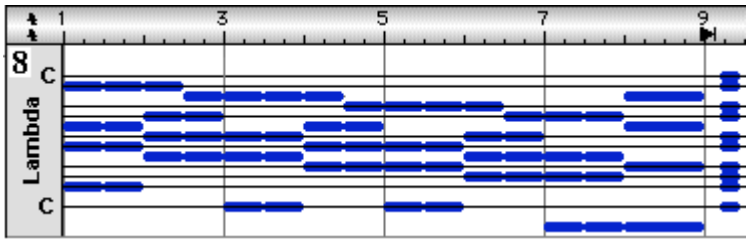

Figure 18: Going down by B-P "1/2 steps"; IIV^o, IIV^o, V down→ IIV^o, IIV^o, V down→ IIV^o, IIV^o, V down→ A^{maj}, A^{maj}, E^{aug}

Chris and I both felt that #7 sounded "cheesy", like a cycle of dominants. I feel like this is quite an accomplishement! To get any microtonal tuning, especially one with no octaves, to sound "cheesy" is not an easy task! He describes progression # 8 as "haunting and eerie", also words that I often use to describe the Bohlen-Pierce Scale sound. Chris describes all of the above chord progressions as "esthetically pleasing, intriguing and unusual." I tend to agree, and feel strongly that these and other "less cheesy" chord progressions can be pieced together to create music that has a strong sense of melodic movement and resolving harmony, but with an added "haunting and eerie" flavor.

The Listening Test

I gave a listening test to two groups of people, with a total group of 9 test subjects. The test consisted of the 8 chord progressions shown above, the 9 modes (7 previously worked out modes, and my 2 new modes), and one 6 minute piece of music written in the Bohlen-Pierce Scale entitled "Stick Men" that I composed in 1992. The piece of music was recorded primarly with same synthesized orchestral string sound (containing primarily odd harmonics) that I used for the chord progression and mode listening examples. It also contained a simple tom-tom drum for rhythmic content, and a vocal line that only happens at the beginning and end. The drums also drop out in the middle section, leaving only the strings. I originally wanted to use two different sounds for each example, however, the test was fairly long and grueling as it was, (well over an hour) and that would have simply made it too lengthy. I also felt that sticking to the exact same sound throughout the test might lead the test subjects to eventually tune out the actual timbre altogether, focusing primarily on the pitch relationships. Obviously, pitch and timbre are ornately tied together in reality, especially when we are considering how the harmonics of different intervals are woven together, however, it is possible to focus on the timbre much less than the pitch relationships.

Chord Progressions: The first two chord progressions were short - only four chords, both starting and ending on the same chord. These are sort of warm-ups for the ears. The next three chord progressions were twice as long, and all three finish on a chord other than what I would consider the "tonic". I meant for these to have a strong feeling of needing to be resolved. The last three chord progressions are twice as long again and are more like little sequences, with rhythmic patterns and motifs. All three land on chords that are the closest I could come to as a tonic, or resolving chord, with what I sensed as a strong final cadence. As we shall see, my ears are tuned a little differently than most of the rest of the world. Each chord progression had four associated questions with five possible answers. There was plenty of room and encouragement to write additional comments. I gave the subjects as long as they needed to write comments and just played the progression over and over with a few seconds in between each time, until all four or five were ready to move on to the next example. I strongly discouraged too much talking, especially about their opinions on what they heard. This added to the grueling quality of the test, as they were dying to spout out their opinions. However, it was still a positive experience for all, and even those who strongly disliked the sound found it extremely interesting.

Modes: Next were the 9 different 10 note scales or "modes" shown in figure 7. I played them in the order shown in figure 5, with my two modes at the end - Walker (Pierce II) and Walker (Delta II) respectively. These last two modes I derived by using my own chord progression examples, and compiling all of the chords I had used with respect to one tonic, and then tried to find the mode out of the existing 7 that would contain most of my chords. I found that by modifying the Moll I (Pierce) mode and the Moll II (Delta) mode slightly, two new modes would be created that contained more of the chords I came up with strictly by ear. As I stated earlier, I did not think these would be the most widely used or dominant modes, because they are each missing at least two of the scale degrees that make up the two main triads. Apparently I didn't use the main triads to a great extent in my own chord progressions. I had made these up by ear before studying to a great degree what earlier Bohlen-Pierce Scale studies had developed, and was not purposefully trying to use the main triads, or taking into consideration any previous knowledge of Bohlen-Pierce Scale harmony. There was not much I could think of doing with the scales for this test other than simply have the subjects pick their "favorite mode". In order to do this efficiently, I grouped them into three groups of three. The test subjects picked their favorites out of each group of three and then separately, one test subject at a time, I had them pick their favorite mode out of their favorite three.

Musical Work: Lastly, the test subjects sat back, with their newly trained (or broken) ears and listened to my six minute Bohlen-Pierce Scale piece entitled "Stick Men". There were four questions associated with this song that were very similar to the questions for the chord progressions. I strongly urged them to put additional descriptive comments and opinions.

Expectations: As a result of this study, I expected to have a better understanding of the concept of chord progressions and modulation in general, and whether the actual “feeling” one gets from a chord progression in the 12 tone equal tempered tuning can be duplicated or approximated in the Bohlen-Pierce Scale. I also hoped to gather enough information in order to draw conclusions that have not been covered formally in Max Mathew’s and John Pierce’s previous experiments, as another small step in the understanding of this rich and harmonically diverse macro-tuning.

Listening Test Results

On the previous 12 pages is a copy of the listening experiment with a complete tally of all 9 test subjects included on each page. Each chord progression has it's own page, for 8 pages total. The two pages that follow show the results of the test subjects picking their "favorite mode" out of the nine modes, and on the final page is their review of the piece "Stick Men".

The answers to the first two questions for the chord progressions are fairly usable, and I was able to extract some useful information out of them. With a couple of exceptions, the answers tend to lean heavily in one direction for each question. However, the results of the second two questions are completely noisy and it is practically impossible to make heads or tails out of the data. My suspicion was that the subjects simply had different ideas as to what the technical definitions of "modulation" and "atonal" were. After asking the test subjects to give me their definition, I found that it was indeed the case that they had wildly different opinions on the two matters.

Questions:	**Chord Progression #**								**Answers:**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Do you get a feeling of "harmonic movement"?	4	2	5	3	5	6	7	5	Strongly (I got a strong sense of harmonic movement)
	4	4	3	3	2	3	1	2	Somewhat (I got a fair sense of harmonic movement)
	1	3	1	3	1			1	Very little (I got a very small sense of harmonic movt)
							1		Not sure (completely undecided)
					1			1	Not at all (I got no sense of harmonic movement at all)
Do you get a feeling of "finality"?	4	5				2			Strongly (It resolves like a final cadence would, to the tonic)
	4	3		1	1	5	1	1	Somewhat (It resolves somewhere, but not to a tonic)
			4	3	1		5	3	Very little (It goes somewhere, but doesn't exactly resolve)
			1	1	1				Not sure (completely undecided)
	1	1	4	4	6	2	3	5	Not at all (It doesn't resolve at all)
Do you get a feeling of key modulation?		1	3	3	2	2	3	1	Strongly (It sounds like it modulated)
	2	1	4	1	3	3	2	2	Somewhat (I get a fair sense of modulation)
		2		1	1		1	2	Very little (I get a very small sense of modulation)
	2	1	1	1	1	1	1	2	Not sure (completely undecided)
	5	4		3	1	3	2	2	Not at all (It sounds like it stayed in the same key)
Do you perceive the chord progression as being in a "key" as opposed to being "atonal"?	4	3	1	2	2	2	3	3	Strongly (It sounds like it's in a key)
	2	2	2	1	3	4	2	1	Somewhat (I get a fair sense of a key)
	1	2	3	5	2	3	2	2	Very little (I get a very small sense of key)
		1					1	1	Not sure (completely undecided)
	2	1	3	2	1		1	2	Not at all (It sounds completely atonal)

This is also a valuable learning process as to what the best questions are to ask. I had purposefully "overlapped" the questions, where one was interdependent on the others. For instance, the answer to "Do you get a feeling of harmonic movement?" would surely have to be "Strongly" if the answer to "Do you get a feeling of key modulation?" was "Strongly". However, I found this to not necessarily be the case. Not only were many of the answers to the last two questions in conflict with the answers to the previous

questions for individual test takers, but the overall answers to questions 3 and 4, are extremely noisy, so I found it simplified things if I chose to ignore that data. Therefore, I concentrated more on the results to questions 1 and 2, which correlated well with my expectations, and found the individual comments of the test takers to be quite interesting and useful. It is very clear to see that, for the most part, the test takers had a clear sense of harmonic movement when they heard the chord progressions. As for question #2 about their sense of "finality", they also answered somewhat closely to what I had heard myself.

If we look at Chris' analyses of the chord progressions, you can see that 1 and 2 resolved to what Chris and I thought of as a I chord, and the answers to their questions indeed reflect this. Two people that did not think these resolved at all were Charles and Pawel, the two test takers who adamantly despise microtonal harmony.

Progression #1: 1 I, IV, II, V^6, I

Progression #2 I, IV^6, I

The next three did not resolve to any kind of a tonic. Most of the test takers felt that it didn't resolve at all, however, some of them answered "somewhat", which, after talking to the subjects gain, I also interpret as a misunderstanding of the question. For the most part, it was felt that these progressions indeed do go "somewhere", but not back to the tonic.

Progression #3 I, IV, VI(?), IV, I, IV, V, I, #IV

Progression #4 I, IV, ?, ?, I, IV, V, I, $^{\#}$IV

Progression #5 I, IV, V, IV, I, IV, V, I, VII^o/IV

The next three were a little bit less clear. In my mind the next three progressions clearly resolve to a tonic, with a slight exception of number 8. There were definitely mixed opinions about these three. Obviously, Chris did not feel that they went to the tonic either. However, it is confusing to analyze due to the sequential stepping down or stepping up of the progressions. I expected them to get a very strong sense of modulation here, however, the answers were again complete noise.

Progression #6 Going down by B-P "1/2 steps"; I, ^{b}VI, V down→ I, ^{b}VI, V down→ I, ^{b}VI, V, $^{\#}IV^{maj}$

Progression #7 Going up by B-P "whole steps"; I^7, IV^7, VII^7, VII^7 up→ I^7, IV^7, VII^7, VII^7 up→ I^7, IV^7, VII^7, VII^7 up→ I, VI^{aug}, III

Progression #8 Going down by B-P "1/2 steps"; IIV^o, IIV^o, V down→ IIV^o, IIV^o, V down→ IIV^o, IIV^o, V down→ A^{maj}, A^{maj}, E^{aug}

The opinions regarding their "favorite modes" were rather noisy as well. In fact, all nine of the modes were chosen to be at least someone's 1st, 2nd, or 3rd choice. The top two rated modes were in fact the Lambda mode and one of the two modes that I developed. The Lambda mode, I agree, is one of the most diatonic sounding modes, with a nice asymmetrical pattern to it, and contains all of the pitches needed to construct the two main "Wide" and "Narrow" triads. I took the liberty to go through every single mode and find every possible consonant sounding chord I could. I made a diagram like the one below for each mode, however, I will only show Lambda since it seems to be the tonic mode of choice, and shows the largest variety of chords. These chords aren't classified yet, to my knowledge, except for the "Wide" and "Narrow" triads.

Possible Chords for the "Lambda" Mode

Freq. Ratio	Note Name	Wide	Narrow	3	4	5	6	7	8	9	10	11	12	13
3/1	C													
25/9	B			X		X		X						
63/25	Bb													
7/3	A	X				X	X	X	X	X				X
15/7	J												X	
49/25	Jb													
9/5	H		X	X		X	X				X		X	X
5/3	G	X			X			X	X	X		X		
75/49	F#													
7/5	F		X				X		X					
9/7	E									X	X	X	X	X
25/21	D				X									
27/25	Db													
1/1	C	X	X	X	X	X	X	X	X	X	X	X	X	X

For the most part, the test subjects felt that the piece "Stick Men" had strong harmonic movement, and moments where a cadence would resolve. They also seemed to get a "fair" sense of key. They had very mixed feelings about whether the song "modulated". The comments were very interesting, and widely varied. Pawel thought that the song, as well as everything else on the listening test was simply "out of tune". Liz thought that it was a good experiment on how to make the "out" sound "in" and that it sounded pretty normal on a pop level. Atu thought it had a "foreign" quality and revealed hidden "sub-tonalities". He definitely was intrigued by this whole listening experience and wanted to know the parameters needed to microtune his synthesizers to this tuning so that he could experiment himself. Charles says the notes make him restless and uncomfortable. He does not like the fact that he can't predict the next note and that he hungers for the "comfort of the traditional scale". Charles is the most unconventional one of the whole bunch, so it is interesting that he is one of the two who are completely unable to accept this tuning. I feel, as I do with Pawel, that it is the "pseudo perfect pitch" ability that they were both born with that has made them "lock" into the 12 tone tuning they have been brainwashed with their whole lives. Olivia and Yann were fairly open to the tuning, and although they were slightly confused by some of the chord progressions, they both really enjoyed this song.

Conclusions

One thing that I had suspected, that I am absolutely sure of now, even with this very small and tentative test, is that one's tendency to enjoy microtonal harmonic relationships is NOT purely cultural. It is cultural that we might find it "unusual" or "different" or "foreign", but NOT a cultural reliance as to whether we will "hate it" or "feel uncomfortable" or "like" it or even "strongly desire" it. In this listening test, I found wildly differing answers and opinions. I believe that it is partially something that people are born with that dictates whether or not they may actually enjoy microtonal harmonic relationships that they are not used to, or whether they only feel comfortable with a tuning they have grown up with. Those born with perfect pitch - and are the most in tune with the 12 tone tuning - have the hardest time relaxing when such music is being broadcast.

Pawel, who adamantly opposes any micro or macro-tuning, has a strange type of perfect pitch. He calls it "grid hearing", while he has not memorized by name what pitches he is hearing, he would be able to tell if a 12 tone piece is all relatively sharp or flat. He is so locked into the 12 tone tuning, anything outside of it is simply "out of tune" in a horrible way. As a musician, Charles is not as trained as Pawel, but I believe that he too was born with some kind of perfect pitch ability. For example, he knows if "Happy Birthday" is played in a different key than he learned it in, and not because of the feeling he gets when he sings it, but purely by listening. Charles considers this tuning a vile insult to music as a whole and both he and Pawel were twitching and shifting uncomfortably throughout the entire test.

Liz, Olivia, and Chris, who do not have any type of perfect pitch (however, Liz and Chris have excellent relative pitch, as does Pawel and Yann) were all sympathetic to the tuning and were more open minded about it, but didn't seem to care or have strong opinions either way. Atu and Yann, both with strong backgrounds performing jazz (perhaps that helped them accept dissonant intervals), were very much intrigued, and took the most time to write comments. Unfortunately, neither of them wrote some of the great comments they made verbally, which they just couldn't seem to keep to themselves during the test! They both commented how the Bohlen-Pierce Scale sounds "new", "fresh", and even "the bomb". They both had very specific opinions as to which chord progressions and modes they liked the most. They just weren't very good at writing their feelings down on paper, but they were definitely verbalizing their positive opinions. It was like a new world had just opened up for them.

Chris Child, who has heard plenty of microtonal music in the past, had similar opinions as I did, for the most part. We could hear 12 tone chord progression relationships that we could loosely compare the B-P progressions to, however the B-P Scale has a totally unique sound and feeling to it. We both get the definite feeling of eeriness and sense an ethereal, smooth quality.

In essence, a thick blanket of "cultural" flavor certainly clouds the test results as we have been bathed in and brainwashed by the 12 tone scale. However, the comments give strong clues that allude to the fact that we are born with the ability to either accept, and even long for, new and different harmonic relationships that we are used to - or not. I believe that those born with the ability to learn some variation of perfect pitch have the hardest time accepting anything outside of the tuning they are raised with. Some can easily tolerate different harmonic relationships than they are used to, but just aren't moved by it enough to go through the trouble of composing in or seeking out microtonal music, and are completely content to only listen to the music of our culture - 12 evenly spaced tones. Their real interest may be in the timbre or rhythmic or lyrical content and not so much in the harmonic content anyway.

I personally feel very strongly moved by certain microtonal harmonic relationships, as I have heard in other compositions, and also when improvising and composing on my own with various tunings. There is a lot to be explored, as each tuning has a different "flavor". For instance, the 19 tone equal temperemant has a tense, tight, and slightly harsh sound to it. Ten notes per octave has a more open, yet neutral sound since the thirds are right in between major and minor. The Bohlen-Pierce Scale has an even more open and fluid, almost alien, sound to it. More tonal music needs to be written in these tunings before we will really know the answers to these questions. The fact is, within our western culture, most microtonal music in the past has been either completely avante-guard and/or atonal. It is possible, if one has the patience to research and develop harmonic content, to write very tonal sounding microtonal music - the music of the future!

Bohlen-Pierce Guitar, 1997

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