Prepared Violin, Timbre Theory and Timbre's Influence on Perception of Consonance/Dissonance

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Abstract

The purpose behind this research is to create a new timbre, through physical modification of the violin, which will then inform a solo piece for violin, and test the theory, which states, that timbre and tuning/scales/harmonies are intrinsically connected; further, to gain a deeper understanding of timbre so as to experiment with a theory of timbre.

Composers have been influenced by timbres for a long time, and in electroacoustic music the creation of new timbres is part of the compositional process since the founding of the electronic-music studio in Cologne.

What this research is attempting to do is to combine these two approaches but with real instruments, in this case specifically the violin.

First there is a research phase where different modifications of the violin are tested. Then from the gathered data the materials, structures, form, etc. of the piece can be generated, and a new piece based on newly formed timbre is created.

KEY WORDS: timbre, scale, tuning, harmony, prepared violin, timbre modification, spectrum, ring modulation, spectral composition, hierarchy, timbre harmony

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Intro

"Timbre, at first entirely ignored in composition, is eventually recognized as an autonomous phenomenon, then as a whole separate parameter; finally, it submerges, or rather encompasses the other dimensions of musical discourse. Thus, minute sonic fluctuations (vibrato, glissandi, spectral changes, tremolos) become not mere ornaments to a text, but the text itself."
Tristan Murail, "Scelsi, De-composer"

In the twentieth century composers (such as Schaeffer, Varese, Scelsi, Stockhausen, Murail, Grisey, etc.) started looking at timbre as an integral part of composition, and for some it did not only become a part of the composition, but the composition itself, or a pre-given, a priori, determiner for compositional structures and processes.

The reason for this shift in focus on timbre, as opposed to melody, rhythm and harmony, has not just aesthetical/musical origins – and benefits. The new strong focus on timbre started with the introduction of non-western musical cultures, as far back as Debussy, and new technological inventions, which permitted the recording and manipulating of sounds. The spectral composers, who originated in France, would analyze many sounds and try to replicate them through orchestration or electronic means.

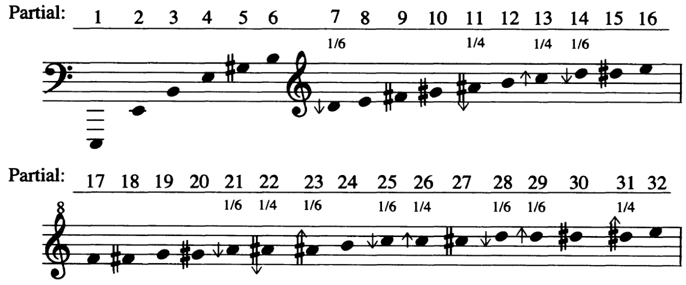
New research on musical timbre led to the discovery of the deep connections between timbre and consonance/dissonance.

"…the perception of "timbre" is closely related to (but also distinct from) the physical notion of the spectrum of a sound. Similarly, the perception of "in-tuneness" parallels the measurable idea of sensory consonance. The key idea is that consonance and dissonance are not inherent qualities of intervals, but they are dependent on the spectrum, timbre, or tonal quality of the sound."
William Sethares, "Tuning, timbre, spectrum, scale", pg. VI

In the book "Tuning, Timbre, Spectrum, Scale", William A. Sethares presented a series of experiments and collected research to show how timbre is involved in our understanding of consonance/dissonance and the corresponding music theory. According to the theory put forth in his book, we could have ended up with a different set of scales/harmonies and rules governing such, if the harmonic series of our instruments were different. For example in Thai classical music, where a 7-tone scale, related to the spectrum of their instrument(s), is used.

There are many more examples which proof that it is possible to create different musical systems which are based on an instruments spectrum, and this spectrum does not have to be harmonic (harmonic meaning an overtone series with integer related partials).

Background



Picture 1: Overtone/ Harmonic series

The harmonic series, or overtone series, is a set of pitches, called partials, which are vibrating with the fundamental (the lowest of the aforementioned pitches). (Picture 1). An instrument has, because of various physical reasons, certain partials from the harmonic series and some inharmonic partials (which are not related to the fundamental by integer ratios). The amount of inharmonic/harmonic partials and their relative volume, are responsible for the perceived timbre of the instrument.

Interestingly, evidence has been found ("Tuning, Timbre, Spectrum, Scale", William Sethares) that there is a relationship between the overtones of a culture's instruments and their tuning, scales, intervals and harmonies. The European tradition has used instruments with a very harmonic spectrum/overtone series and so they developed a musical system closely related to this particular series. Other, non-European, cultures have used different instruments, which led to a different musical system of scales, intervals and harmonies, for example in gamelan music where not even an octave is in an integer relationship. Here the definition of consonant and dissonant intervals is based on whether an interval occurs early or very late; or not at all, in the spectrum of the used instrument. This way of thinking about consonance/dissonance can be explained by psychoacoustics. Helmholtz discovered that different degrees of dissonance/consonance (with sine-tones) depend on the amount of beating between the two pitches; how close the two frequencies are to each other.

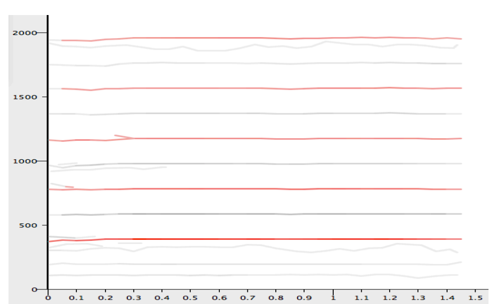
In the late twentieth century the two composers Tristan Murail and Gerard Grisey started a compositional style called spectral composition. The name comes from the fact that they analyzed the spectra of instruments, or other sounds, and composed their music accordingly.

Other composers who were working on purely electronic music, such as Karlheinz Stockhausen, started working on creating their own timbres and altering them over the course of a single piece to create tension and release through timbral dissonance/consonance.

These two domains, creating new timbres and spectral (acoustic) music, have until today not been merged very often. This has various reasons, one of them being that it is impractical to acoustically alter an instruments timbre (except for the use of mutes and playing techniques, where some spectral composer certainly have been successful at merging these two aspects). The research on the relationship of scales, intervals, harmonies, and the used instrument's timbres, has revealed what new possibilities could emanate from unifying these two concepts.

> "The history of musical styles suggests constantly changing sensibilities of rhythmic, melodic, harmonic, tonal, and timbral materials, and it seems undeniable that there are musical styles, undreamed of today, that will develop in the future."
> William Sethares, "Tuning, timbre, spectrum, scale", pg. 320

In this Paper some images of spectral analyses are shown (example: picture 1). The numbers on the left side correspond to the Frequencies, measured in hertz, and the numbers at the bottom are seconds. The red lines are the overtones and fundamental of the played note and the other lines are partials outside of the harmonic spectrum, which are colored according to their volume from black (loud) to light grey.



Picture 2: Example of a Spectrum

Research Phase I

First I had to experiment with different materials to find a suitable violin modification that would produce an interesting new timbre. This meant I had to find ways to modify the violin strings that wouldn't damage the violin, which were relatively easy to attach and which would not fall of during the process of playing the piece.

The second step in the research phase was to analyze the recorded sound's spectrum (overtones), for which I used the software SPEAR (http://www.klingbeil.com/spear/).

These five modifications seemed like they could work well:

Thin Foil

First we (me and my research assistant Nicolas Ordonez) tried to wrap the thin foil around multiple strings at the same time. Neither on the bridge nor at the neck was the result convincing. Next we tried to wrap it around an individual string (A-string) at various locations and found that when positioned right after the bridge it produced an interesting effect, and it stayed in place while playing.

Play Dough

We tried to attach small pieces of play dough onto the string to give it an uneven weight, which would have changed its overtone content. Sadly the play dough didn't stick enough as to resist the string's vibration and so we had to dismiss this idea.

Shoelace

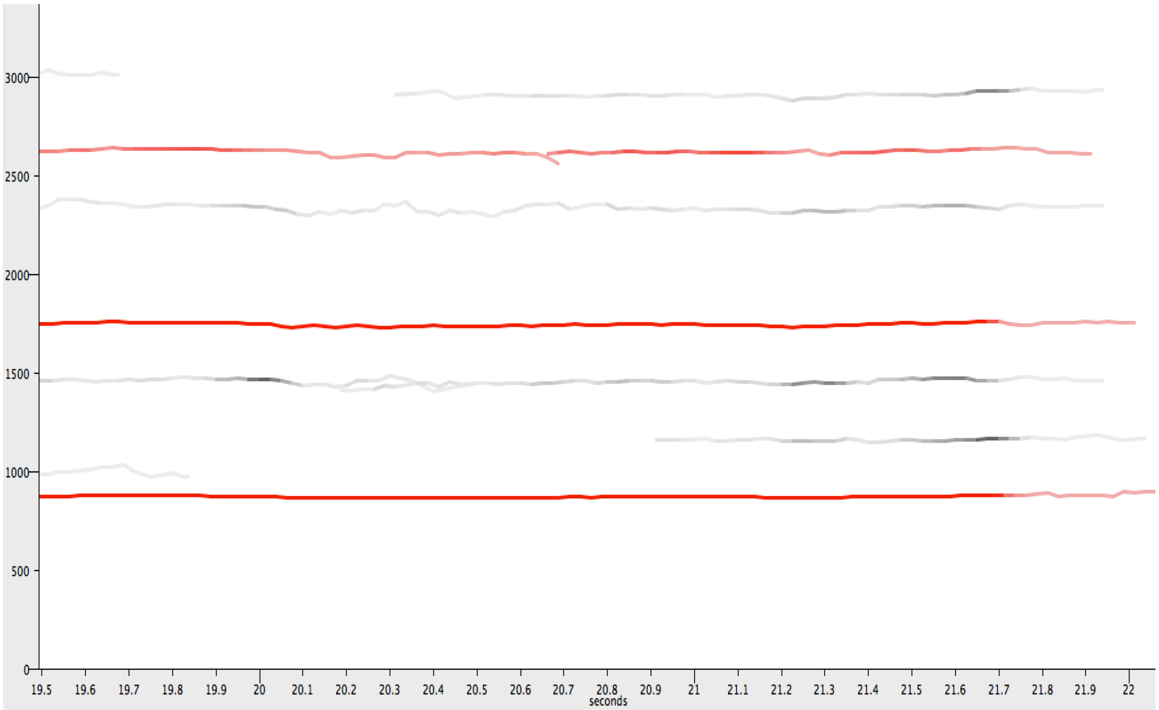
The shoelace had a similar effect to a mute. The only effective way of using the shoelace that changed the timbre significantly was wrapping it lightly over all strings toward the end of the fingerboard. Sadly, at this position the shoelace is still very muting and it affects all strings, so I decided against this preparation.

Sandwich Bag Twist Tie

With this modification we found the most effective way was to wrap it around the string, tightly enough so that it wouldn't move and not to tight to completely mute the sound.
This modification proved to be very effective. The played pitches were still clearly audible but there was a lot of 'noise', which means there were a lot of extra partials vibrating because of the twist tie.

Cooking Twine

When wrapped around a single string the cooking twine creates a slight timbral change. This is due to it acting as a node and creating a few rather prevalent extra partials (picture 2).



Picture 3: Cooking Twine Spectrum (A-String). Highlighted are the overtones, and fundamental, of the note played.

After recording these different string manipulations and doing some spectral analysis with Spear, it was possible to make a selection for the most effective and suitable procedures with which to change the violins timbre. For me, the Cooking Twine and the Sandwich-Bag Tie were the most satisfying modifications.

Looking at the spectral analysis it becomes evident that with the S-Bag Tie the violin string gets many additional, equally loud, partials. This produces a continuous, and relatively quiet, noise-like timbre, while the fingered pitches are still clearly audible.

The Cooking Twine has a completely different effect on the timbre of the violin. Through the analysis it became clear that the twine acts as a node creating extra partials and so changing the overtone content of every pitch played on the string. This is ideal for my purposes because most pitches will have a completely new and unusual set of overtones. This will create a different set of consonant (or dissonant) pitches/intervals.

Research Phase II

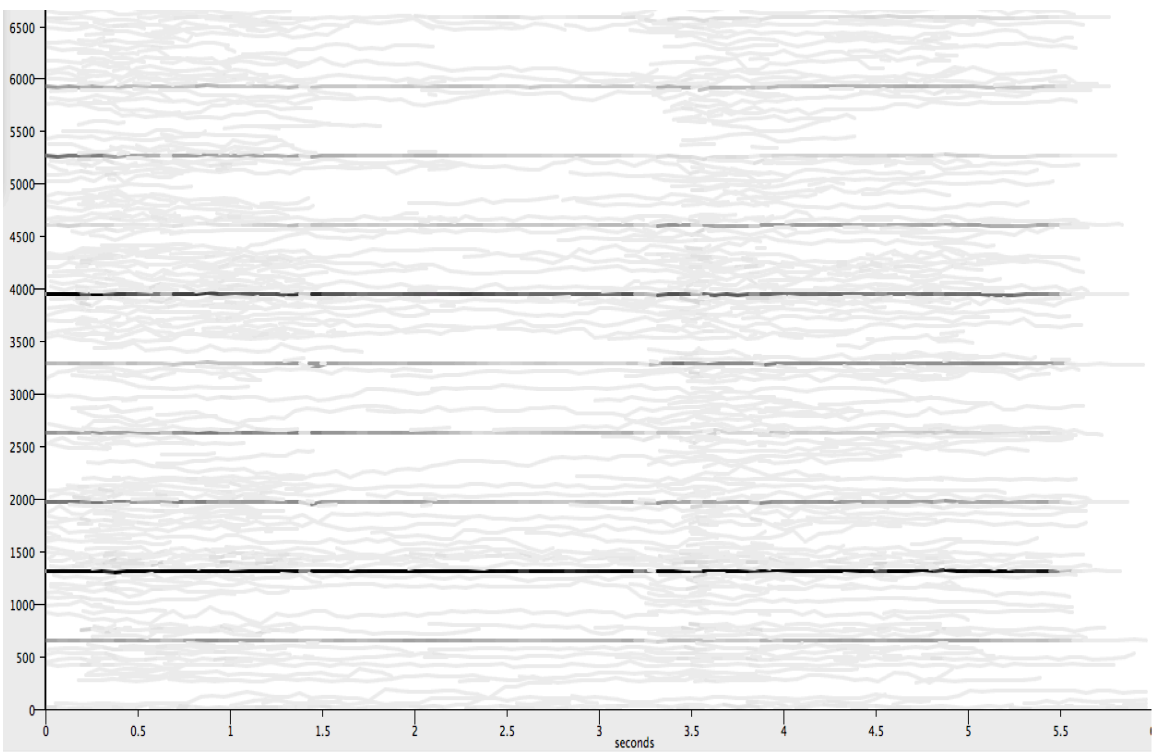
To gain a deeper understanding of what happens with the two string modifications selected in Research Phase I, further sound analysis was necessary and so more recordings had to be done.

Cooking Twine

For the sake of understanding better what the cooking twine does when attached to the violin string, I tried to attach it at a specific note. We wrapped it three times around the string starting at the note A6 on the D-String and on the note E7 on the A –String, and attached it to the fingerboard with scotch tape. The resulting sound wasn't as distinctly different from the normal violin sound as it was in research phase I. The analysis showed some indication of nodes created at the twine wrapping points, but it wasn't strong enough to be absolutely certain if it in fact did function as a node. This must be due to the fact that we attached it very loosely.

Sandwich Bag Twist Tie

The twist tie was wrapped around the E string starting at a B7 and also taped onto the fingerboard. This time we didn't wrap it tightly and so the resulting sound has less noise, but there are still a lot of extra partials (picture 3).



Picture 3: Spectrum of E-string modified with a twist tie

Because this cooking twine analysis didn't verify the findings of the previous research phase, where it acted as a node, I decided to do another research phase and collect more samples.

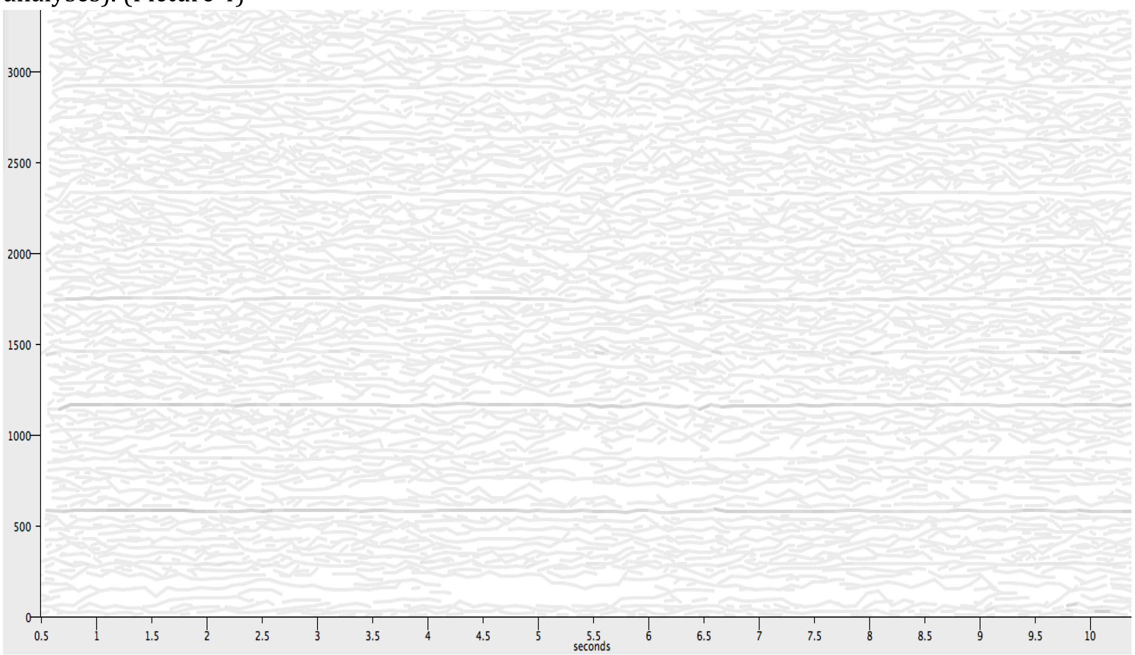
Research Phase III

Since I had another chance of recording with my violinist, I also decided to try out a new modification namely a rubber band.

Sandwich Bag Twist Tie

This time the sandwich bag twist tie was attached, with scotch tape, to the D-String. It was wrapped around 5 times and the first wrapping was positioned around an E6.

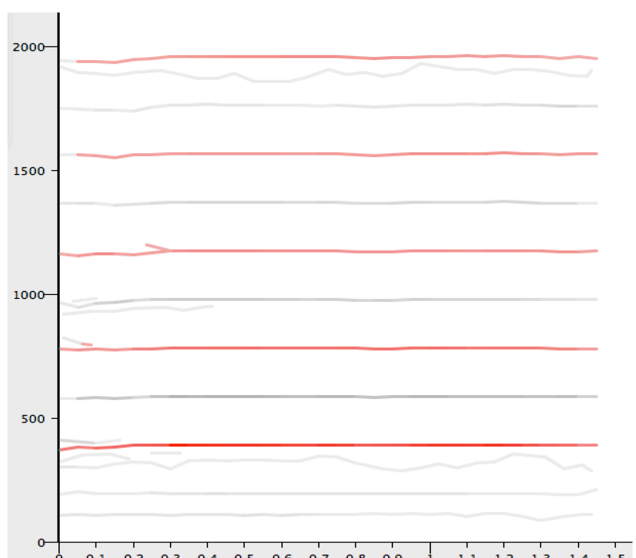
Analyzing the spectrum it became obvious that the twist tie created many extra, relatively equally loud partials, which explains the sound's noise like quality (exactly as observed in the previous analyses). (Picture 4)



Picture 4 : Sandwich-Bag Twist Tie Spectrum

Rubber Band

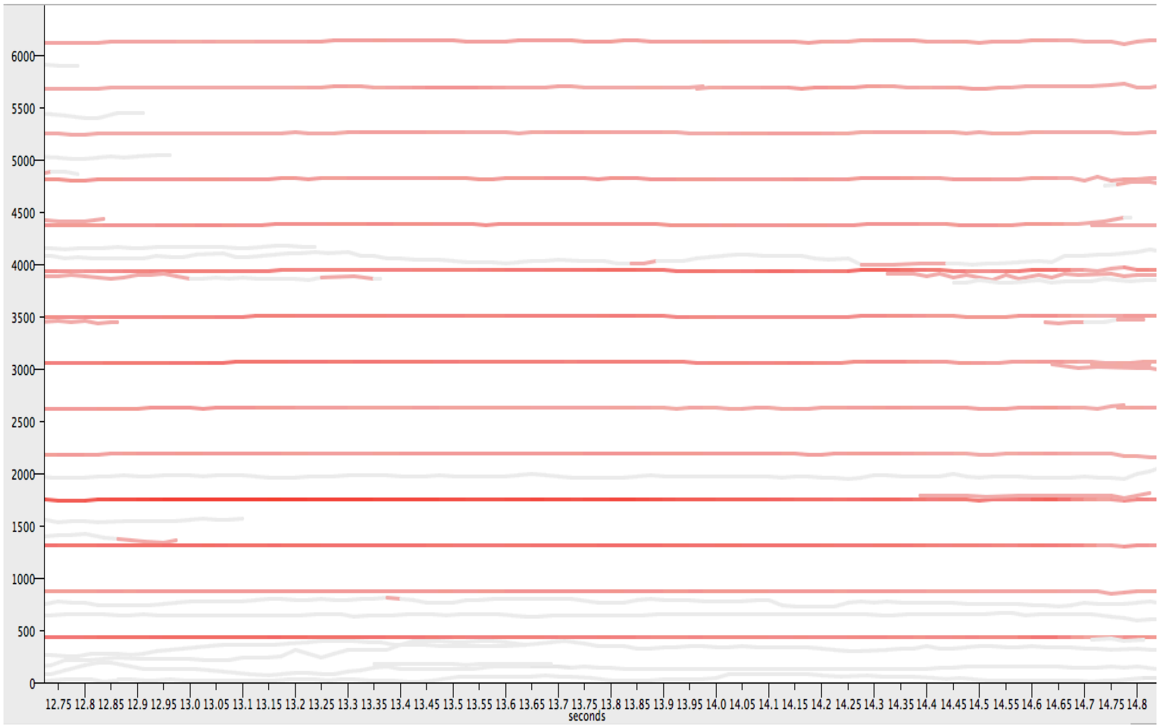
The rubber band was first wrapped around the G-String and attached at the fingerboard where the pitch A5 is produced. This modification acts as a node, which also moves around quite a lot because of the vibrations of the string.



Picture 5: Rubber Band Spectrum
(open G-String harmonics are highlighted)

Cooking Twine

Since it wasn't evident in the previous research phase (Research phase II) whether the cooking twine functioned as an extra node, it was important to position the cooking twine so that it wouldn't be attached at a point where a partial of the open string would occur. We attached it on the A-string around a B6 and wrapped it, again, three times around the string. This time the analysis showed a clear node created by the cooking twine.



Picture 6 : Twine Spectrum (A-string harmonics highlighted)

For the twist tie and the cooking twine there is no further research concerning their sound necessary since it seems quite clear how they change the spectrum of the instrument. What is not clear yet, is what method is the most efficient for their attachment.

The rubber band, on the other hand, still needs more data, especially because the node was moving a lot and this might be avoidable. Furthermore, a rubber band with another thickness might create a different spectrum. The rubber band used in this version was fairly thick.

Research Phase IV

Cooking Twine

Since I already had some good sound recordings and analyses of the modification with the twine, I took this opportunity to try out another way of attaching the twine. The twine was attached with a knot on the D-string at Ab6.

According to the analysis the fundamental has become very quiet and the second partial (D5) is now the loudest. The twine seems to behave exactly like a ring modulator. Ring modulation is done by combining two frequencies which then produce difference and summation tones. It seems very likely that the cooking twine acts as a ring modulator since most of the sounding partials can be explained in this way.

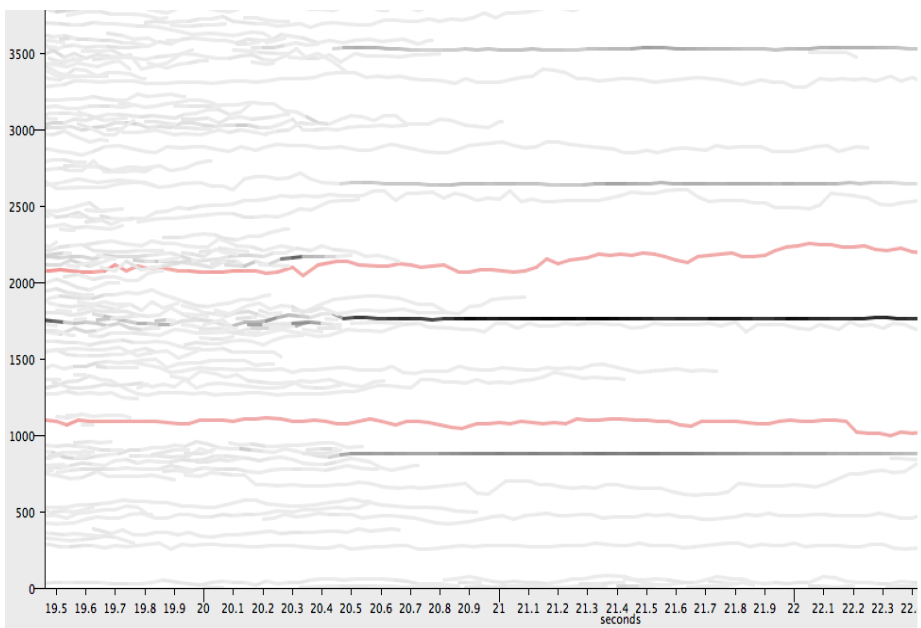
Sandwich Bag Twist Tie

With the twist tie I also tried a different approach. It was wrapped around the E-string at Bb5, only once, and then taped onto the fingerboard to keep it from moving. It was also wrapped around much tighter than in the research phases II and III.

This version of the twist tie makes the overtone series and its fundamental less stable. There isn't as much 'noise' content to the sound as in the previous two research phases but the resulting sound is harsher.

Rubber Band

This rubber band, as opposed to the one in research phase III, was thin, and knotted around the A-string at Eb6.



Picture 7: Thin Rubber Band (Highlighted: Db6 and Db7)

The analysis shows that this preparation makes the fundamental disappear and strengthens the fourth partial (the same pitch but two octaves higher). It also makes the partials less stable and adds other partials to the spectrum, resulting in a rich spectrum. From this it became obvious that the rubber band acted as a node – and a ring modulator. But because it's overtones seem to be more pronounced they might act as ring modulators too, which would in turn explain the vast amount of partials in the spectrum.

We also recorded a rubber band with a thickness between the one used in research phase III and the thin rubber band. It was knotted around the D-string at around Ab5.

With this rubber band the fundamental and its overtones are less prevalent. The resulting sound is, similar to bowing close to the bridge, deprived of a strong fundamental. When playing a scale the sound is very hard to control and easily becomes unpleasant.

This particular research phase emerged to be very informative and clarifying. The thicker rubber band is not very suitable for the piece because it is not easily controllable. The thin rubber band on the other hand creates a very interesting and serviceable timbre.

Both the rubber band and the cooking twine act as a ring modulator, which is a property that's very suitable for testing the relationship of dissonance/consonance and timbre, and also allows for the creation of many distinct timbres on the same string.

Wrapping the twist tie to tightly does not produce a sound that could be used in this piece since it is very unstable and uncontrollable.

Research Conclusion

By doing the four research phases some very useful and desirable modifications have emerged. The twist tie wrapped around the string, as in research phase II and III, has a very stimulating timbre both compositionally and aurally.

The other two modifications that would be very compelling to work with are the thin rubber band (research phase IV) and the cooking twine knotted around the string (research phase IV).

Using a ring modulator on an instrument has already been implemented, most notably - and for the first time -, by Karlheinz Stockhausen. When discussing his piece Mantra for two pianos and ring modulators he proposes

> "…a principle for a complete new harmonic concept in music."
> (Karlheinz Stockhausen, "MANTRA" (1973) British Lectures),

which could be derived from the use of the ring modulator and its effect on the timbre of an instrument.

To elaborate, the ring modulation will result in a more and more complex harmonic spectrum the further away the played, or fingered, pitch gets from the modulating frequency, or in this research from the node. The more complex a harmonic spectrum gets; the more dissonant it becomes, because it incorporates more intervals than the one before it, which makes the timbre feel/sound denser.

Generating Structures/Timbre Harmony

"I think the tone becomes perceptible by virtue of tone color, of which one dimension is pitch. Tone color is, thus, the main topic, pitch a subdivision. Pitch is nothing else but tone color measured in one direction. Now, if it is possible to create patterns out of tone colors that are differentiated according to pitch, patterns we call 'melodies', progressions, whose coherence (Zusammenhang) evokes an effect analogous to thought processes, then it must also be possible to make such progressions out of the tone colors of the other dimension, out of that which we call simply 'tone color', progressions whose relations with one another work with a kind of logic entirely equivalent to that logic which satisfies us in the melody of pitches."
Schoenberg, "Theory of Harmony" 1983, pg.421

The idea behind this research was to create a piece of music whose structure, and "harmonic" language, etc., grow from the newly created timbres. Surprisingly the research phase did not only lead me to the attempt of formulating a new set of rules, for pitches, rhythms and gestures but also to the possibility of creating a work which can contribute to the formulation of a timbre theory.

Schoenberg was the first to consciously consider a theory of timbre, which is similar to our theory of pitch. Since positing this idea, many different composers, theorists and scientists have worked on timbre theory, for example: Stockhausen with his ring modulation, the spectralists with their timbre based composition, Dr. Kaija Saaraiaho with her noise/sound axis and Dr. Fred Lerdahl with his perception based research – Lerhdahl is among the first to attempt formulating a general theory.

Dr. Fred Lerdahl argues in his paper "Timbral Hierarchies", that there needs to be a way of establishing a hierarchy of timbres, or a set of rules, by which different timbres relate to each other. A hierarchy requires a "psychological anchor"; a fundamental against which different degrees of deviation are measured. In my exploration, as in Stockhausen's "Mantra", the anchor is the performed note that corresponds to the modulating frequency of the ring modulator. Thus, the further away from the anchor a performed note, the more 'dissonant' (complex) the timbre becomes.

"This leads to a second important difference between pitch and timbre: pitch admits octave (or periodically recurring) relationships, whereas timbre does not."
Dr. Fred Lerdahl, "Timbral Hierarchies", pg. 144

In "Timbral Hierarchies" Dr. Lerdahl also describes the problem of the aperiodicity of timbre, because periodicity allows for "...network of musical relationships describable by mathematical group theory (see Longuet-Higgins, 1962a,b; Balzano, 1982)."(Dr. Fred Lerdahl, Timbral Hierarchies, pg. 144). Being able to perceive groupings, of timbre, allows us to create another possibility for mental anchors - for re-recognizable timbral groups/structures.

In the case of the ring modulation there is periodicity. If one plays the octave below, or above the modulator frequency, it will create (almost) the same timbre as if playing the same frequency and there is a periodicity in timbre. In this particular composition I'm experimenting with this hypothesis for timbre harmony on the strings with the cooking twine and the rubber band modifications.

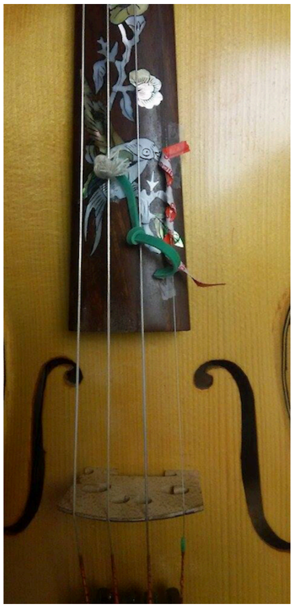
Since timbre can change our perception of dissonance and consonance concerning pitches and intervals, I can't help but wonder: Are there musical elements that can change our perception of consonant or dissonant timbre? Can we perceive a complex timbre as consonant? By treating the twist tie modification, which has a very complex timbre, as an arrival point for the whole piece, I might be able to make this complex timbre sound 'consonant' (make it sound like an arrival point).

In similar fashion to composers such as Gerard Grisey and Tristan Murail, I also plan to derive the musical gestures and "harmonic" language of this work from the newly created timbres. All of the resultant timbres have very unstable partials—the rubber band and the twist tie more so than the twine—, which suggests the use of portamenti and quick micropolyphonic movements that take place in intervallically limited ranges.

Pitches/intervals are chosen according to the timbre, as to show the change of consonance and dissonance according to timbre, and to enhance the perception of the timbre. Maybe it is also possible to make a timbre, not just the pitches, sound dissonant by using intervals/pitches which are not part of the timbre's spectrum.

Composing the Piece (Title: "Reconsider Dissonance")

Once I decided upon the positioning for the modifications, I had to calculate all the resultant tones, which would occur due to the ring-modulation of the nodes, created through the modifications. The previous analyses then guided me in deciding which resultant tones, and/or overtones, would be strongly present in the new spectrum/timbre. These tones I then treated as the consonant pitches and the intervals between them as the consonant intervals of the timbre. Since the modifications acted like a ring-modulator, I had to calculate the resultant tones for every note executed on the modified strings. This constant changing of the spectrum, and timbre, of the same string also allowed me to build a timbral harmonic progression, or hierarchy. At the beginning, and in the middle, of the piece I treat the timbres with spectra close to the harmonic overtone series as consonant and timbres with more inharmonic spectra as dissonant. As the piece progresses, I try to 'modulate' to an inharmonic timbre, making the dissonant/inharmonic timbre feel consonant, by using dissonant pitches in the simpler timbres and consonant pitches (pitches that are part of the spectrum) with the inharmonic timbres.



Picture 8: Final Violin Preparation

Finally, at the end of the piece I make noise (the most inharmonic timbre) sound consonant and pitches sound dissonant by the same means as with the previous inharmonic timbres. The effect of making the pure noise timbre sound like an arrival point is strengthened by the use of many different and frequently changing timbres in the section beforehand. The constant varying of timbre makes complex timbres seem more consonant than simple/harmonic timbres and the most inharmonic timbre is noise.

In addition, I decided to support the timbres with electronic processing by intensifying the spectra in different ways, due to the fact some of the created timbres otherwise might not have been loud enough.

Summary

I found a way to modify the violin and to arrive at three very distinct and new timbral modifications for the instrument. This research has allowed me to create a successful physical ring modulation and to investigate the theory of timbre, and to further the understanding about correlations between timbre and other musical elements.

There is a lot of further research needed to gain deeper understanding of how timbre and our perception of consonance/dissonance correlate, and how to formulate a universally successful and useful timbre theory.

It would also be interesting to try to create other timbral modifications for our current instruments, such as the use of 3D printed strings/mouthpieces and the attaching of other objects.
A further subject of inquiry opened up by this research is the detailed formulation of the rules governing the intervals, harmonies, etc. of these particular newly created spectra/timbres.

Acknowledgments

I would like to thank Nicolas Ordonez for working with me during the research phase experimenting with different violin modifications, and Dr. Derek Hurst for his help and advise during the whole process.

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Software

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  http://www.klingbeil.com/spear/