Constraint Schemata, Multi-axis Movement Modeling, and Unified, Multi-parametric Notation for Strings and Voices

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Introduction

This article discusses my approach to topographical mapping, boundary spaces, and physical modeling in two recent works employing a newly developed, unified multi-parametric notation system. In particular, it examines the ways in which limited collections of physical action types can "push against" constructed, dynamic, multi-planar bounding windows. The friction between these two forces is at the heart of the sonic and physical gestural material of my recent work and encourages unusual, unexpected, and often unpredictable materials to emerge. The discussion of both of the two works—*Second String Quartet* (2010) and *A painter of figures in rooms* (2012)—will involve three stages:

1. Explaining the unique notational system devised for the instrumentation and the ways in which multi-planar, multi-dimensional movements are reduced to a two-dimensional notational image (principally through the use of color).
2. Discussing the constraint schemata employed, outlining the possible planes and axes of motion as well as the kinds of techniques devised to restrict possible movements on those planes.
3. Detailing the approach to gestural modeling on each of the available movement planes, including a discussion of the collisions and recombinations of gestures and the ways in which the resistance between the gestural modeling palettes and the movement constraint schemata produce unpredictable compositional “accidents" that are the source of sonic and musical invention.

Second String Quartet (2010)

My recent work has centered on the development of a unified notational system for multi-parametric compositional and performance techniques. It takes my earlier tablature work (beginning with 2004's *The Crutch of Memory*) as a starting point, with highly specific, prescriptive, choreographic actions stratified across multiple, physiological aspects of sound production (through various forms of instrumental decoupling), and combines those performative instructions into a single notational image. That is, in these two recent works, I have developed a notational system that takes information that had previously been dispersed across numerous staves and compresses that information onto a single staff, depicting the space of the possible movement on the

instrument.[1] The reasons for this new approach are numerous, but the two principle concerns were a) to somehow integrate a multi-layered, dispersed, stratified notation into one that was much more immediately assimilable by the eye, making the instructions not only easier to read but also more direct and immediate as an interface with the performer, and b) to move from a very digital, stratified notational space—that is, one that predominately notates discrete *points* (through numbers, letters, symbols, noteheads, etc.)—to a smooth, continuous notational space that better represents the actual topography of the instrument and the fluidity of possible motion across that space.

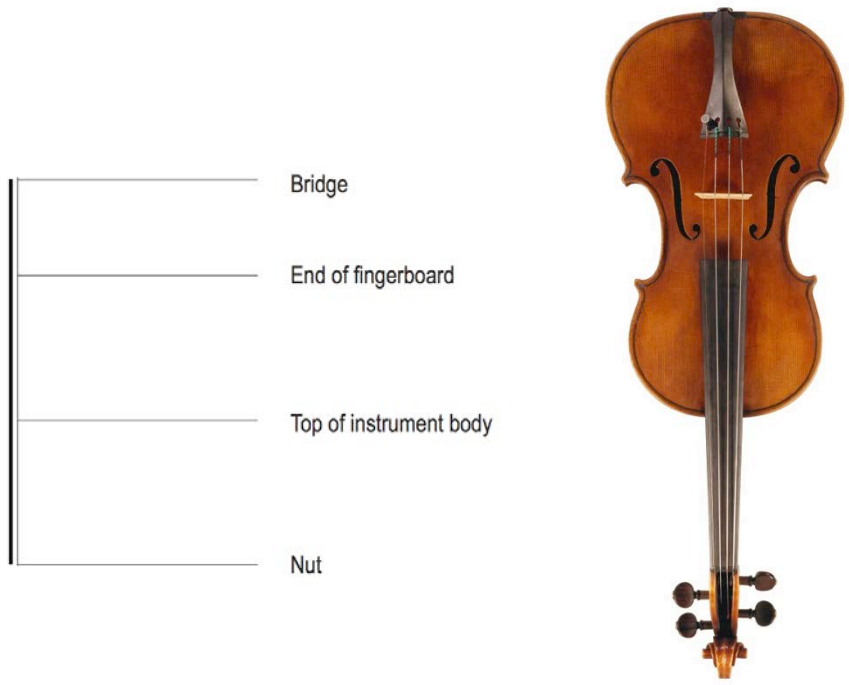
Notation

The notation for *Second String Quartet* starts with a staff that specifies the full vibrating length of the string, with the bridge at the top of the staff and the nut at the bottom, with two guidelines in the middle to indicate the end of the fingerboard and the top of the instrument body (see Example 1). All information on the staff is indicated proportionately, and differences in distances between instruments have been calculated proportionately, as well (that is, violin, viola, and cello have staves of differing heights, and the proportional positions of the two guidelines are also adjusted accordingly).[2]

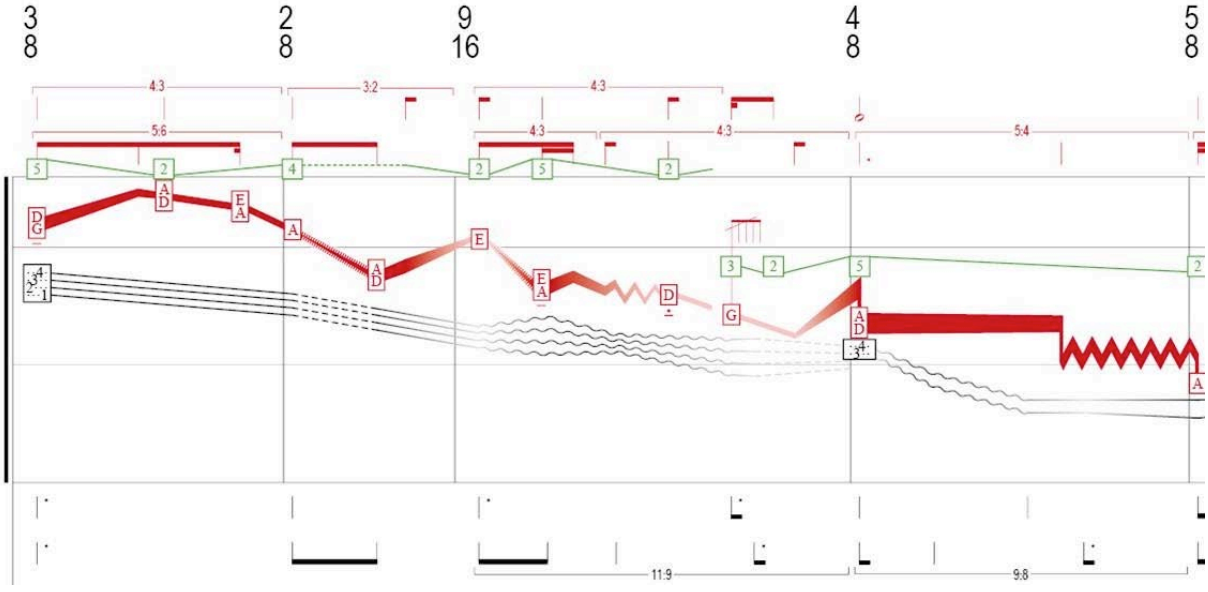
The activities of both hands are notated on this single staff, and, crucially, the full vibrating length of the string is available to the right hand for bowing or pizzicato actions —the right hand movements are not constricted to their normal location on the instrument, but instead can appear anywhere along the string, including "behind" fingered pitches—and the full length of the fingerboard is available for the left hand. The two hands are differentiated on the staff through the use of a multicolored notational system. The left hand is notated in black (with grayscale variation), while the right hand is notated principally in red (with pink, purple, and blue variation) and green. The rhythms for the left hand are shown in black beneath the staff, and the rhythms for the right hand are shown in red above the staff. (The rhythmic stems do not extend through to connect to their respective activities primarily to reduce the number of vertical lines running through the staff, though it is worth acknowledging more generally that rhythmic information has been pushed farther and farther to the notational periphery in quite a lot of my work in recent years.)

[1] This earlier approach to tablature notation is discussed in detail in the article, "Determinate Action/Indeterminate Sound: Tablature and chance in several recent works," *Facets of the Second Modernity,* New Music and Aesthetics in the 21st Century, Volume 6, Mahnkopf, Schurig, and Cox, eds. (Wolke Verlag, June 2008). Score excerpts of these earlier works are also available at http://aaroncassidy.com

[2] I gathered a collection of common measurements for each of the three instruments from various instrument builders and simply averaged the results. (The bridge is at the top of the staff because almost every string player I have ever met views the bridge as being "high." Movement up the fingerboard towards the bridge produces higher pitches, and as such bow movement towards the bridge is better represented by ascending lines, while bow movement up the fingerboard towards the nut is better represented by descending lines. To date I have only met a single string player—a cellist—who prefers movement towards the bridge to be designated by descending lines.)



Example 1: *Second String Quartet* staff layout



Example 2: *Second String Quartet*, Violin I, mm.1-4

Example 2 shows a typical passage from the *Second String Quartet*. Note that a number of rhythmic subdivisions are present simultaneously, and that these rhythmic units connect to various kinds of changes of direction, thickness, width, gesture, and so forth. Throughout the work, each hand can have up to three independent rhythmic layers (connecting to their three planes of movement, discussed below), though there is an overriding limit of a maximum of four total rhythmic layers at a time for any one instrument.[3]

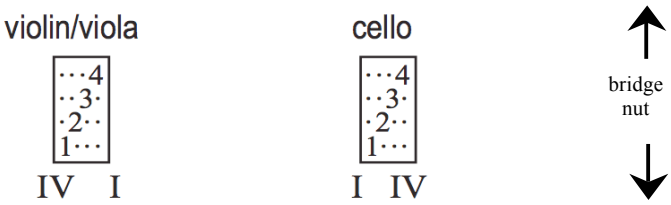
The location of the left hand fingers on the fingerboard is indicated in the boxed enclosures—the dots are placeholders for the four strings, and the graphic is read from left to right as the fingerboard appears from the position of the performer, and from "low" to "high" in the same manner as the string notation more generally (see Example 3). (Note that the layout of these boxes is different for violin and viola than it is for the cello, mimicking the respective layouts of the strings.) The movement of the fingers is indicated by the lines extending from these boxes, showing the trajectories of the fingers up and down the fingerboard, including changes in the width between the fingers, finger pressure (black = normal finger pressure; grey = harmonic finger pressure), and various kinds of finger gestures, including vibrato, finger pressure trills, and trills and tremolos (see Example 4). Trills and tremolos use the same "finger pressure" notation, with the addition of two slashes to clarify that both fingers are assigned to the same string. Trills and tremolos also occasionally appear "behind" the fingered pitch.

The bow movement of the right hand up and down the string is notated similarly (see Example 5). The boxed red letters indicate which strings are in contact with the bow or are to be plucked, including bowed tremolos between two adjacent strings (again shown with two slashes, similar to the trill/tremolo notation of the left hand, and showing the order of string alternation). The graphical location of the string letter name and the lines connecting those letters indicate the position of the contact point between the right hand and the string.

As shown in Example 6, the colored lines extending from the boxed enclosures indicate the position of the right hand along the length of the string, the pressure exerted on the string by the bow, whether the hair or wood of the bow is employed, as well as a number of gestural actions, including various kinds of vibrations, wiggles, mordents, etc., and transitions between these states.[4] This right hand movement is persistent throughout the piece, and as mentioned above the right hand quite frequently occupies spaces on the string behind the left hand. As such, the soundworld of the piece is often one of scraping, sliding, and sweeping, the right and left hands moving frequently and rapidly up and down the fingerboard. Pitch is generally quite unstable, and much of the piece sits in an unstable grey zone between pitch and noise.

[3] These passages of maximum rhythmic density are fairly rare, however. Quite a lot of the piece is limited to a single rhythmic strand per hand.

[4] Pizzicato actions simply omit the extended colored lines; in these cases, line thickness/pressure indications are simply traded for conventional dynamic symbols.



Example 3: Sample finger position graphs

	normal finger pressure
	harmonic finger pressure
	gradients indicate transition between normal and harmonic finger pressure
	"harmonic trill" alternating between normal and harmonic finger pressure
	"hammer-on trill" (rapidly alternating between heavy finger pressure/finger percussion and open string)
	exaggerated vibrato
3 2	harmonic pressure trill
4 1	trill "behind" fingered pitch, with transition from harmonic pressure to finger percussion

Example 4: Left hand finger pressure, trills, vibrato, and tremolo notation

Example 5: Right hand (bow/pizz.) string assignment contact point indications, including tremolo notation

	*col legno tratto* (wood only), with very light pressure
	½ *col legno* (wood plus some hair); slightly stronger pressure, but still very light
	very light pressure (ca. *pp-p*)
	"ord" pressure (ca. *mp-mf*)
	slightly heavier pressure (ca. *f-ff*)
	very heavy, aggressive pressure (ca. *ff+*)
	transition between lightest *col legno tratto* to heavy pressure
	transition between "ord" pressure and maximum pressure
	jagged lines represent a rapid back-and-forth motion along the string (always as fast as possible)
	serrated lines with white hash marks along the sides indicate a pulsed, "bowed vibrato" produced by rapidly changing bow pressure
	bowed mordent (fast alternation to the string above or below)

Example 6: Right hand bow pressure and gesture notation

The final component of the right hand notation is the up- and down-bow movement, which is indicated in green (see Example 7). This layer primarily indicates bow *speed*, as the notation specifies the amount of bow that moves across the string and the duration of that movement. The bow is divided roughly into five equal "zones," with 1 towards the tip and 5 at the frog. Up- and Down-bow motion is indicated with green diagonal lines between boxed numbers, and dotted horizontal lines instruct the player to maintain the same zone in contact with the string.[5]

As with the left hand notation, note in Example 2 that the two red, right hand rhythmic layers each connect to different aspects of movement. In this case, the lower of the two layers refers to the movement of the bow up and down the string and various gestural activities on this plane; the upper layer refers to bow pressure and to the up-/down-bow motion. For each phrase of the piece, in each instrument, there is a recombination or realignment between the rhythmic layers and which aspects of movement they refer to.

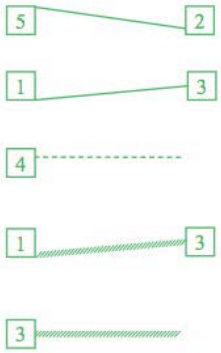
Constraint schemes

These notational principles establish three planes of movement for both the right and left hands. Example 8 outlines the available movement planes for each hand, including "horizontal" movements up and down the fingerboard, "vertical" changes of finger or bow pressure, and "lateral" movement across the strings and across the bow.

Gestural movements are enacted on these six planes, but those movements are not boundless. These each undergo independent, dynamic constraint schemata that restrict the available movement space for each of the six planes. These constraint schemata are linked to phrases (extending the principles of phrase construction that I have been working with since 2001)—each of the six planes maintains its own constantly shifting constriction space, moving from one available window of motion at the beginning of the phrase to another at the end.

On the "horizontal" plane, these constraint schemata are relatively straightforward. Examples 9 and 10 below show the spatial constraint windows for the same passage shown above in Example 2. One can immediately see not only the way in which the movements of the hands push against their bounding limits but also the way in which the right hand often reacts contextually to the additional layer of constriction provided by the left hand. (The specific types of gestural motions available within each of the hands also help to prescribe how the hands interact with their spatial constraints; this will be discussed in detail below.)

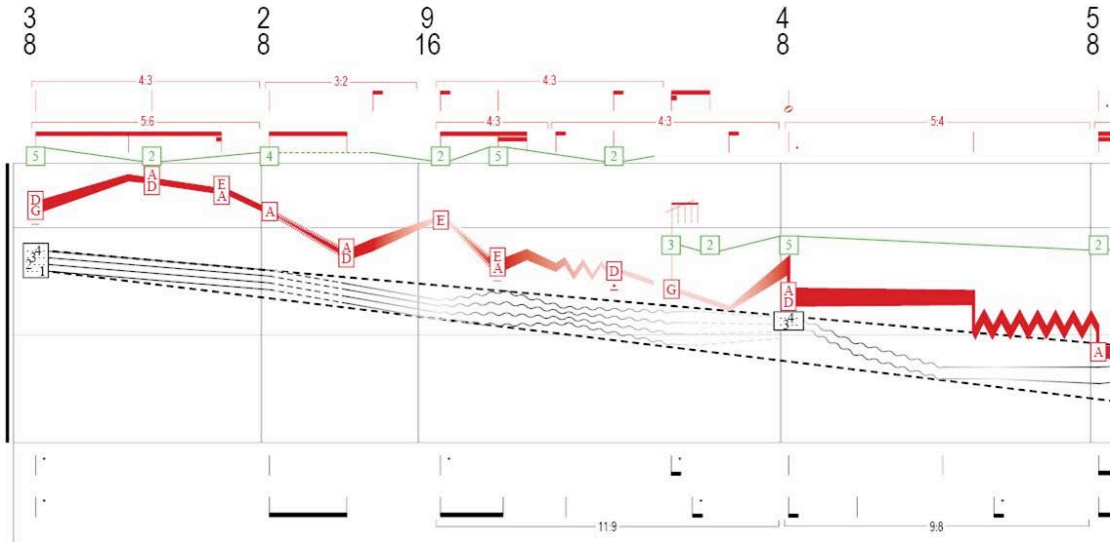
[5] Because the notation collapses four dimensions (three dimensional movement plus time) into a two-dimensional space, one of the movement axes needed to be subsumed onto an existing notational plane. Although the ascending and descending diagonal lines of the bow movements occupy the same plane as movements up and down the string, this seemed the best solution of all the many versions of the notation that I made. Because the bow activities are, in some ways, a superimposed notational layer, the location of the bow direction information moves around the score somewhat so as to facilitate reading. An effort was made to always show this information as close to the other two layers (left and right hand position) as possible.

	down-bow from zone 5 (frog) to zone 2
	up-bow from zone 1 (tip) to zone 3 (middle)
	dotted horizontal lines indicate maintaining the zone position, with no up-/down-bow motion (resulting in various brushing and grinding sounds)
	diagonal slashes indicate bowed tremolo (in this case a rapid bowed tremolo moving from bow zone 1 to bow zone 3)
	bowed tremolo without changing bow zone

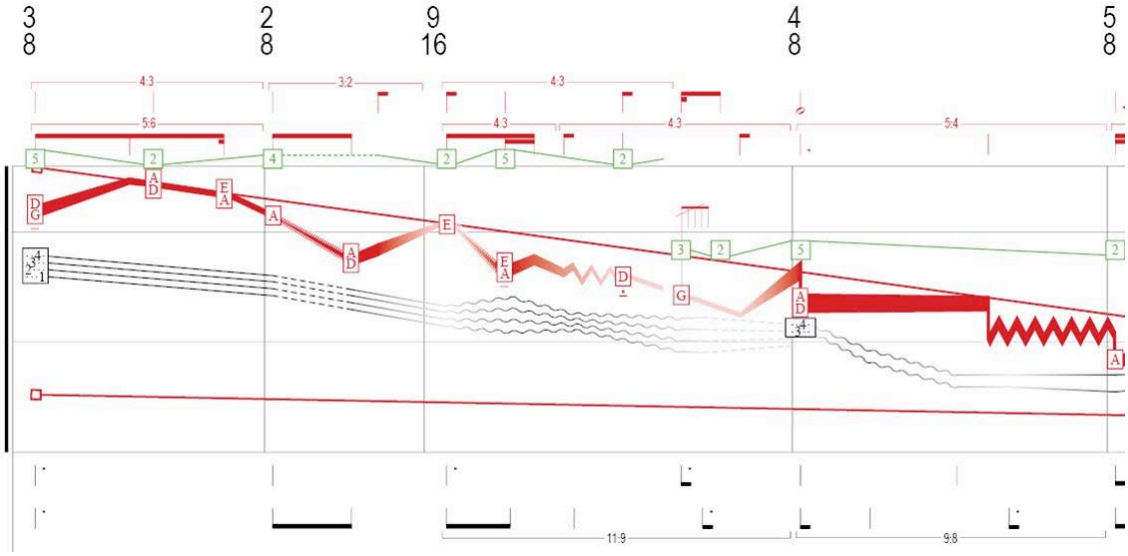
Example 7: Up-/down-bow movements, including bowed tremolo notation

Left hand	**Right hand**
horizontal • Space available up/down fingerboard • Movement gesture types	horizontal • Space available up/down fingerboard • Movement gesture types
vertical • Available finger pressure	vertical • Available bow pressure
lateral • Available strings	lateral • Available bow space (1-5) • Bow movement gesture types

Example 8: Three-dimensional movement planes for left and right hands



Example 9: Left hand constraint windows, Violin I, mm. 1-4



Example 10: Right hand constraint windows, Violin I, mm.1-4

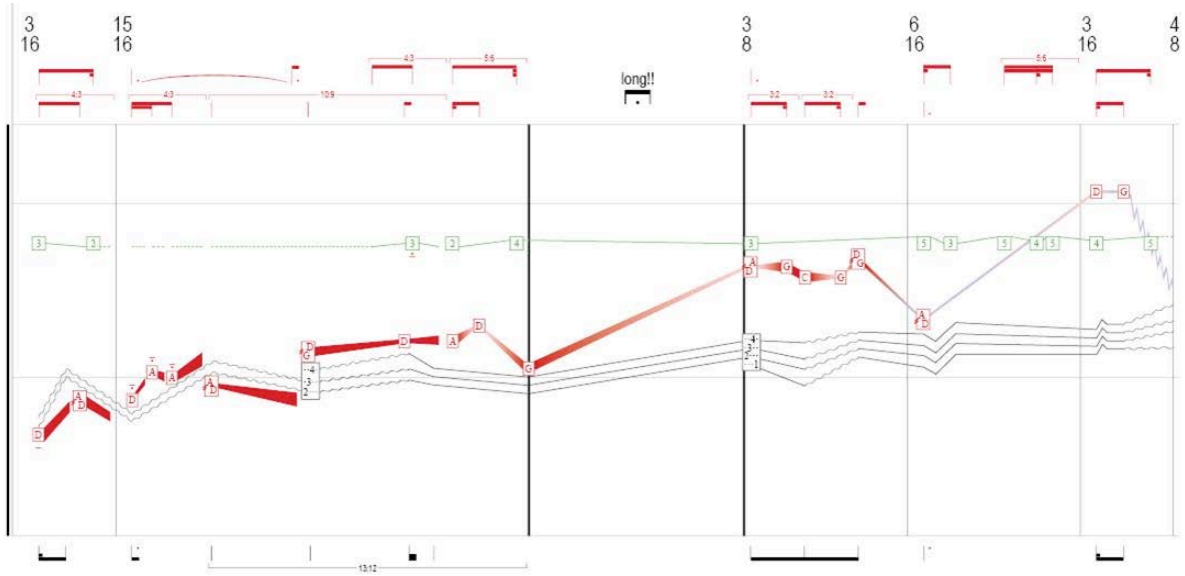
A further example (Example 11) shows a much more interesting scenario, in which the hands occupy the same small space, constantly crossing back and forth. The right hand begins "behind" the left hand and jumps back and forth twice before continuing on the normal side of the fingered pitches. Here the interaction between the two constraint schemes combines to create a unique "accident" (to borrow a term from the painter Francis Bacon that I've used frequently in my recent work), requiring a bit of compositional problem solving. Example 12 shows the left and right hand bounding lines, which are quite clearly in conflict for much of the opening two bars of the passage. The leaping of the right hand is the direct result of this conflict—it is a gesture (first a physical one, then a sonic one) that is largely a byproduct of the constraint schemes, as the two hands attempt to fulfill their assigned behaviors and movement types (more on which in a moment) while colliding with the bounding lines and with each other.

This same approach to the constriction of available movement space is present on all six planes, not simply along the length of the string. Example 13 shows a brief excerpt of one of the sketches for the piece, laying out the constraint schemata for all six planes. For the right hand, "bow availability" establishes which subset of the five bow zones are available, "bow pressure" establishes which of the six pressures are available, and "rh" entries establish the available space up and down the string. For the left hand, "string availability" establishes which of the four strings are available at any given time,[6] "finger pressure" establishes degrees of finger pressure along with an expanding and contracting palette of trill, tremolo, and vibrato gestures, and "lh" entries and "finger width availability" establish both the movement of the arm up and down the string and the amount of space between the fingers (a principle drawn directly from earlier works such as *The Crutch of Memory*). The dark, vertical lines in the sketches indicate phrase groupings, and one can see that some of the constriction spaces are continuous from one phrase to the next (the left and right hand movements up and down the string, for example), whereas others reset at the beginning of each phrase.

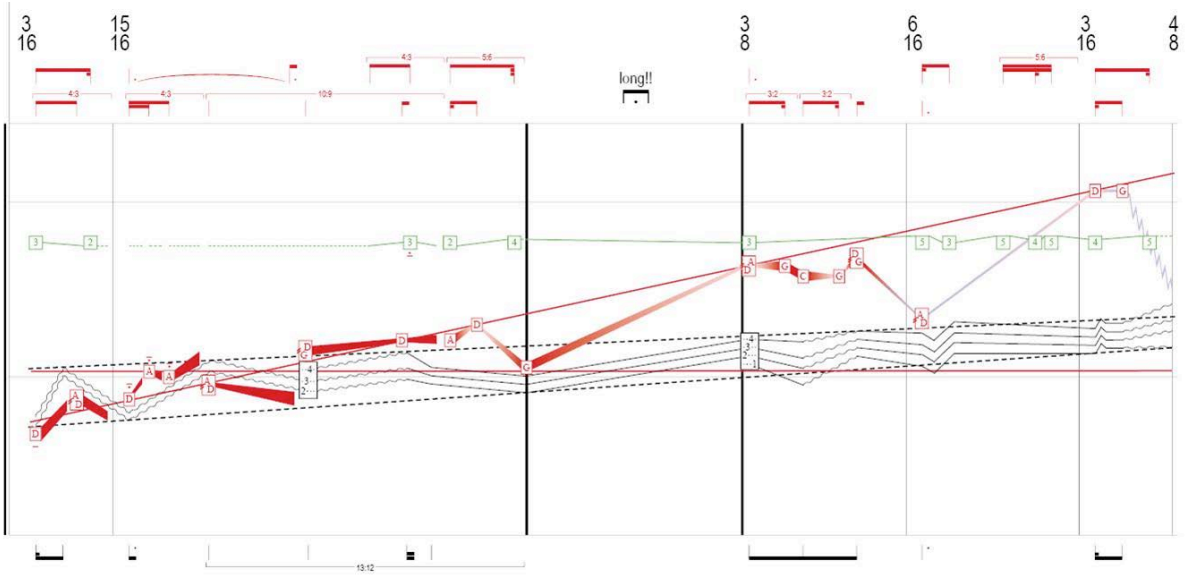
A comparison between the first five bars of the sketches in Example 13 with the excerpt in Example 14 shows how these numerical constraint schemata transfer onto actual physical spaces and movements. For example, the right hand moves from an available space of 9-10, at the very bottom of the string near the nut, to 1-10, the full length of the string, over the course of the phrase. (Note again that right hand movement is typically contingent on left hand movement and is also often constrained by practicalities of tempo, gesture, etc.) At the beginning of the phrase, the bow only has zone 2 available—as such, this passage begins only with sweeping, brushing gestures from the bow, locked in place without up- or down-bow movement—and slowly adds zone three later in the phrase. Similarly, the available bow pressure for this particular phrase begins only with pressure 5 available (from the six pressure levels shown in Example 6), a rather heavy bow pressure, moving to a range of pressures 2–4 by the end of the phrase, incorporating ½ *col legno tratto* bowings (indicated by the light purple lines). The change in finger widths is also reasonably easy to spot, moving from the two

[6] The constraint scheme runs from 0 to 5 for a simple, practical reason: because these pairs of numbers are only given for the beginnings and endings of phrases as nodal points, if the outer limits for the system were 1 and 4, those strings would only ever appear sporadically and at beginnings/ends of phrases. The 0/5 system meant that those string " spaces" opened up sooner.

narrowest finger width options at the beginning of the phrase to a locked width 3 by the end.



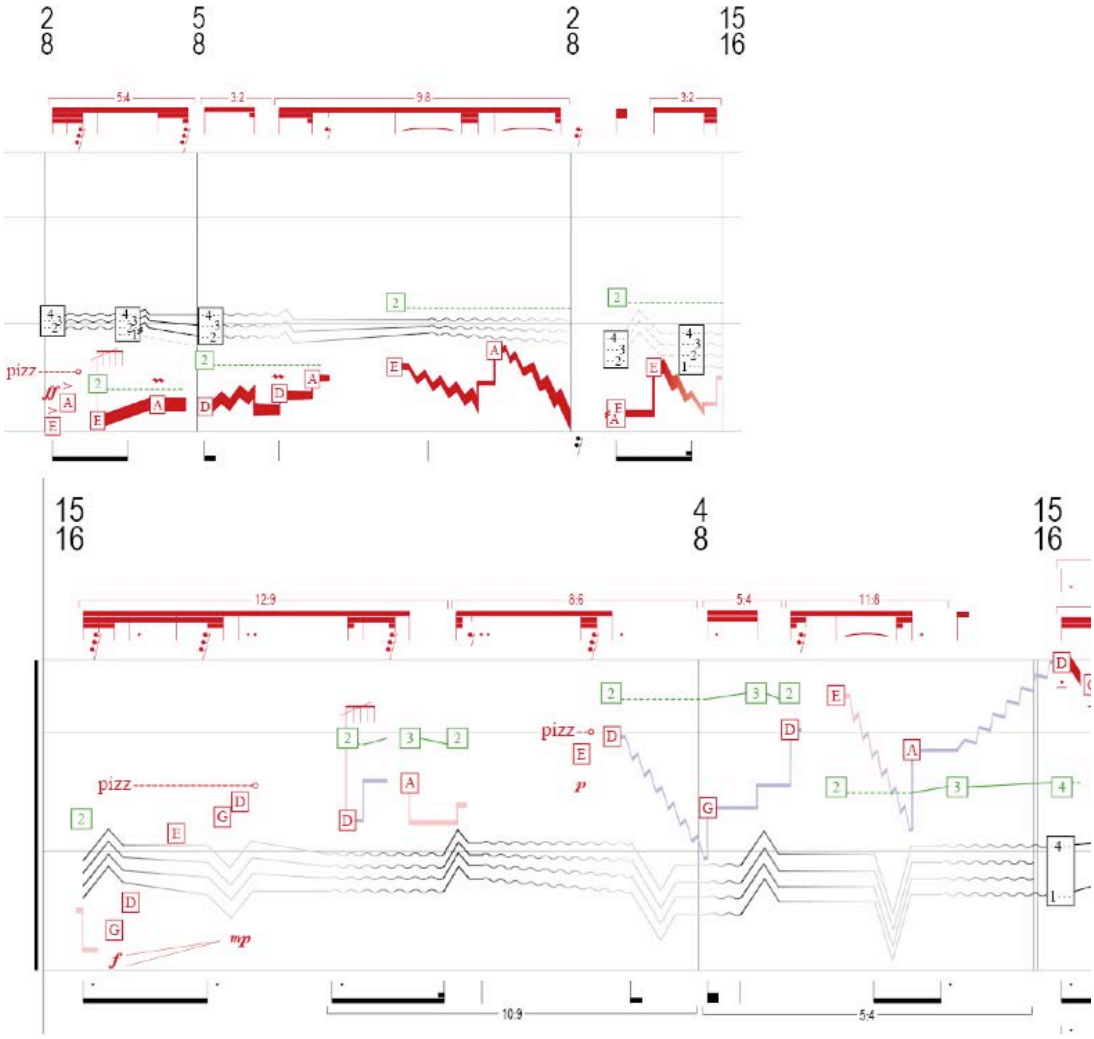
Example 11: *Second String Quartet*, Cello, mm. 103-7



Example 12: Right and left hand movement guides, Cello, mm. 103-7

A	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
	17	18	19	20	21	22	23	24	25	26	27	28
	2	5	4	15	4	15	2	2	3	5	9	2
	8	8	16	16	8	16	16	4	8	8	16	4
TEMPO						72						accel.
violin 2												
rhythmic independence - RH												
bow position	1					1						
bow direction	1					1						
bow pressure	1					2						
rhythmic independence - LH												
arm position	5					4						
finger widths	5					6						
finger pressure	5					4						
bow availability (1-5)												
bow - 1	2				3	5						2
bow - 2	2				2	4						1
bow pressure availability (1-6)												
pressure - 1	5				4	5						3
pressure - 2	5				2	5						6
string availability (I-IV)												
string - 1	1				0	3						0
string - 2	3				5	4						4
finger width availability (1-4)												
fw - 1	1				3	3						1
fw - 2	2				3	1						1
finger pressure availability (1-7)												
fp - 1	1				1	3						4
fp - 2	5				3	6						6
rh - 1	9					10						
rh - 2	10					1						
lh - 1	4					4						
lh - 2	5					10						

Example 13: *Second String Quartet* sketches excerpt, Violin II, mm. 17-28



Example 14: *Second String Quartet*, Violin II, mm. 17-21

Gestural models

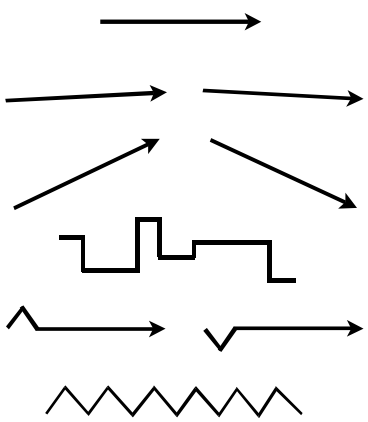
While this explains the ways that I dealt with limiting the available movement planes in the work, it doesn't yet explain what actually happens inside of those windows. Within these constriction spaces, all physical movements on all six movement planes draw on a collection of extremely simple gestural models. They are intentionally reductive, almost childish in their simplicity. The goal was to construct a palette of available movements that are repeatable, limited, and traceable and that can easily maintain their essential character on each of the six movement planes.[7] Example 15 outlines these gestural models. Their simplicity is obvious, as is, I hope, their recognizability when passed between movement planes. The sixth model, for example, would include fingered trills and tremolos, subtle vibrato, rapid zigzag left hand movement up and down the string, bowed tremolos, bowed tremolos alternating between adjacent strings, finger pressure trills, bow pressure trills, etc.

As with the organization of available movement spaces, the palette of available gestural models shifts for each phrase in the work and does so independently for each of the six movement planes. The beginning and end of each phrase is assigned a particular number of gestural models, with those movement types accumulating or disappearing across the duration of the phrase.

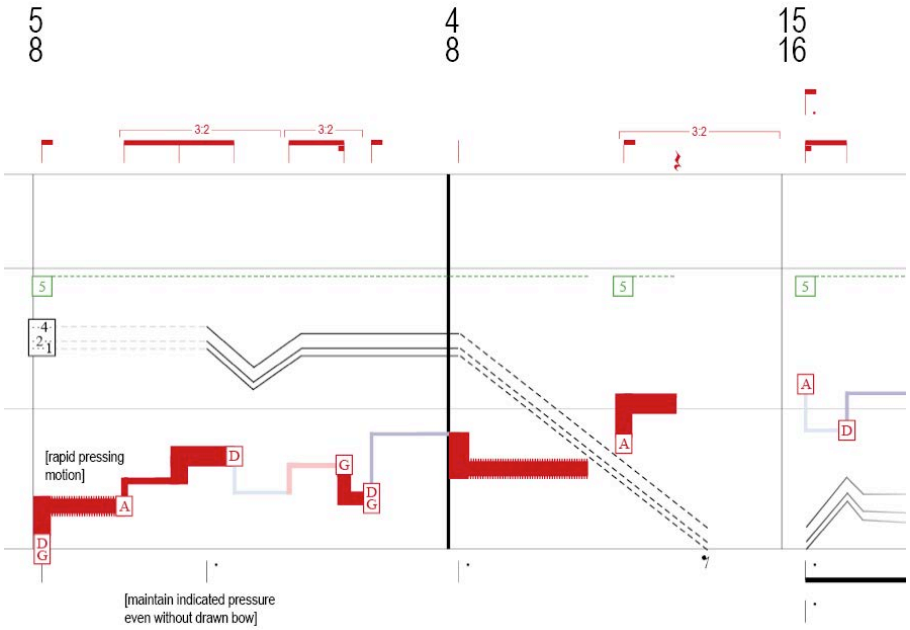
Crucially, it is the interaction between these many layers of constriction schemes—available movement windows and available gestural models for each of the six planes, combined with their independent rhythmic and tempo considerations—that provide for me the most interesting and challenging aspect of the work's composition. This multi-layered system frequently establishes unexpected conflicts, frictions, and "accidents" that lead to unique sonic outcomes that, quite frankly, I don't think I would have imagined on my own. Example 16 shows my favorite example of this kind of conflict from the work. Here, there is a highly unlikely combination of prescribed movement types and available spaces in which that movement can take place. In the right hand, the bow is constricted to zone 5, locked near the frog without up- and down-bow movement. The right hand's available space is initially limited to small space near the top of the string near the nut, well behind the left hand's fingered pitches, with the left hand eventually encroaching on that space in the second bar. And the right hand has a vast range of bow pressures required (from minimal to maximal, or pressures 1-6) but only one movement type up and down the string (type 4 from Example 15, rapid, step-like mechanical shifts) and, simultaneously, a "bowed vibrato" gesture in the right hand pressure layer (type 6 from Example 15). Coupled with the left hand's pressure type gestures (also two versions of type 6 from Example 15 of both light and heavy finger pressure trills), the resulting sound is something quite fascinating, with skittering, unstable crackles and clicks, particularly at the beginning of the second bar through the

[7] A very similar approach appears in the work *And the scream, Bacon's scream, is the operation through which the entire body escapes through the mouth (or, Three Studies for Figures at the Base of a Crucifixion)* (2005-09) and its three extractable works. The process is detailed in the article "Gestural modeling and compositional constraints in *Being itself a catastrophe, the diagram must not create a catastrophe (or, Third Study for Figures at the Base of a Crucifixion)*." *Sonic Ideas/Ideas Sónicas*. CMMAS, Vol 3, No.1, Spring 2011.

combination of heavy bow pressure that rapidly shakes up and down with quick, spasmodic, pressurized pulses on the string without up-/down-bow motion along with independent, flickering, hammered-on glissandi in the left hand. It is, quite simply, a physical gesture and a sonic result that I could not have imagined. It appears only as a solution to an extremely restricted space established by the movement and gestural constriction schemes.

	flat
	micro
	up/down (max)
	steps/leaps (mechanical, vertical)
	mordent
	vibrato/vibration/pulsation

Example 15: *Second String Quartet* gestural models



Example 16: *Second String Quartet*, Viola mm. 109-110

These unpredictable, "emergent" circumstances and behaviors are the source of much "forced" invention in the work. The compositional systems and methodologies frequently back me into a compositional corner, erecting what seem to be intractable obstacles, and it is in confronting and pushing back against these restrictions and obstructions that new spaces, new materials, and new sonic worlds emerge.

A painter of figures in rooms (2012)

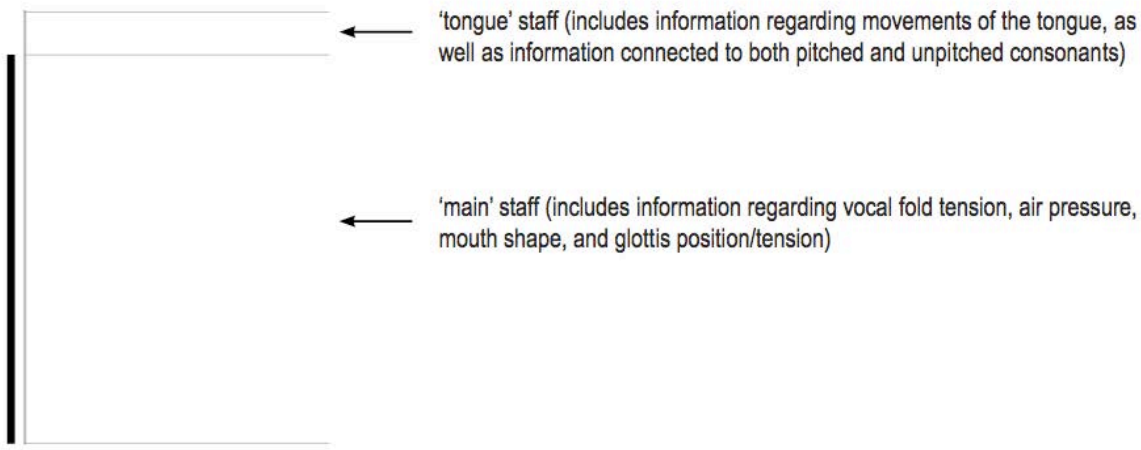
A painter of figures in rooms, for eight voices, takes a very similar approach to the stratification, control, and recombination of layers of physical sound production through restrictions on both "movement spaces" and "gestural models." The significant difference of course is that rather than working through the performer as interface with their instrument here the performer *is* the instrument. The decoupled actions that were not only physical but also visible and tangible are here hidden, internal, highly personal, and to a certain extent quite mysterious.

The materials of the piece consist of a stratification of the voice through a separation of the physiological components of vocal sound production. As with the *Second String Quartet*, this decoupled approach serves to generate unpredictable, unexpected, "emergent" or "discovered" sound worlds, and again, as with the quartet, this approach serves to foreground the process of experimentation, embedding the experimental process in the piece (perhaps even *as* the piece), rather than viewing compositional experimentation as a stage of research that precedes the composition of the piece.[8]

Notation

The notation too is similar to the *Second String Quartet*, beginning with a main staff that outlines vocal fold tension (more on which below), combined with a variety of symbols and colors that specify particular physiological states, energies, and actions (see Example 17). The various components of the notation refer to sung, vocalized sound production (as opposed to spoken sound production), though the sounds resulting from the intersection of the stratified components often differ quite dramatically from the sounds of a more conventional singing and include a range of distortions, whistles, shrieks, multiphonics, groans, etc., which are often unpredictable in nature and will emerge as the result of the activities represented in the notation, rather than being expressly notated. Furthermore, the piece may be sung by singers of any voice part, and as such the degree of variation from one performance to another is considerable.

[8] For more on this approach, see "I am an experimental composer," a paper delivered initially at the COMPOSITION-EXPERIMENT-TRADITION conference at the Orpheus Institute in Ghent in February 2012 and reprinted online at http://aaroncassidy.com/experimental-composer/



Example 17: *A painter of figures in rooms* vocal staff

The top and bottom lines of the "main" staff outline the extremes of tension of the vocal folds, with the bottom line indicating maximal looseness and the top line indicating maximal tension. While this space ostensibly indicates *pitch*, from low to high, it is essential to note that the notation refers to physiological states and not to sounding results. As such, any connection to pitch is relative rather than absolute—the highest and lowest lines never refer to specific pitch reference points, and additional reference points (such as a central line, for example) are intentionally avoided. Indeed, even *horizontal* "pitch" lines on this staff will not *necessarily* relate to sustained static pitches, as the actual resulting pitch may fluctuate slightly as other parameters change. (For example, changes in the glottis position/tension layer will often dramatically affect resulting pitch, even as the relative vocal fold tension remains static.)

The thickness of the lines on the "main" staff, as shown in Example 18 refers to air pressure from the lungs and diaphragm. As with the vocal fold tension notation, the air pressure notation is obviously most easily interpreted as "volume," though in practice, as above, the combination of air pressure with other parameters (vocal fold tension and glottis position/tension, in particular) precludes any direct, predictable mapping of the available air pressure levels onto *dynamics*. (For example, high air pressure coupled with a low register and loose glottis position might in fact be softer in its resulting volume than low air pressure coupled with a high register and pinched glottis position.) Five air pressure levels are employed in the score (the dynamics shown below connect roughly to the resulting volume with normal vocal production in a controllable middle register and serve only as a relative guide or reference point), as well as transitions between those five levels.

Six mouth shapes are used in the work.[9] As with the other components in the notation, it is physiological states that are notated, *not* resulting vowel sounds. (The vowel sounds shown in the example are given only as an initial reference point to help

[9] Mouth shapes shown in boxes remain static/consistent until the next indicated mouth shape. Mouth shapes enclosed in circles are transitional—the singer shifts gradually from the encircled mouth shape to the next indicated mouth position (which itself might be circled/transitional or boxed/static).

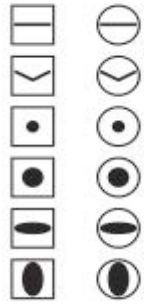
describe the mouth shapes.) Because of the independent motions of the tongue, in particular, there is very little direct correlation between mouth shape and resulting vowel sound. The six mouth shapes are meant to be exaggeratedly "pure," repeatable, and absolute.

The most ambiguous layer yet perhaps the most critical to the final sounding result, glottis position/tension is indicated through the color of the lines on the main staff. In a sense, this layer is most akin to what some singers refer to as "placement" (including both glottis tension and position and the position of the soft palate). Five tension/position/placement states are used in the work:

1. loose: extremely breathy, wispy, diffuse, unfocused tone; at the lowest air pressure levels, "pitch" may be frequently unstable and even scarcely unrecognizable
2. normal: ordinary, sung vocal production; pure, focused tone
3. nasal: a reasonably small shift from normal sung tone towards a slight nasalization (not an aggressively nasal sound, but rather a subtle, though recognizable, timbral shift)
4. closed: fully nasalized (velar nasal), as in the English "ng." Obviously the effect of mouth shape changes is minimized/mitigated with the "closed" position, as the air escapes primarily through the nose rather than through the mouth. Similarly, because tongue position movements are significantly limited when coupled with "closed" vocalizations, these movements are typically surrounded in square brackets to acknowledge that the complete notated range of motion might not be available
5. pinched: extremely tight, pinched, and constricted, resulting in a rough, abrasive, texture. This tension will often generate quite unpredictable and unstable results, including growls, various states of vocal fry, vocal whistles, multiphonics, etc.[10]

This main staff also includes the notation for various types of tremolo, vibrato, *trillo* pulsation (created through rapid glottal closure), and singing while inhaling.

[10] We discovered in rehearsals that the term "pinched" was not particularly helpful for the singers, and over the course of the development of the piece it was replaced by a number of other descriptive words that better described the physiological action in a way that allowed this tension/position to be more readily transferred between various registers of the voice and different levels of air pressure.

	ppp (minimal air pressure)
	pp – p
	mp – mf
	*f – ff*
	*fff* (maximal air pressure)
	closed mouth ("mm," as in humming)
	lower lip touching top teeth ("v")
	round, narrow, pursed lips ("oo")
	exaggeratedly round ("oh")
	spread, horizontal ("ee" or "eh")
	tall, vertical ("ah")
	loose
	normal
	nasal
	closed
	pinched

Example 18: Air pressure, mouth shape, and glottis tension/placement notation

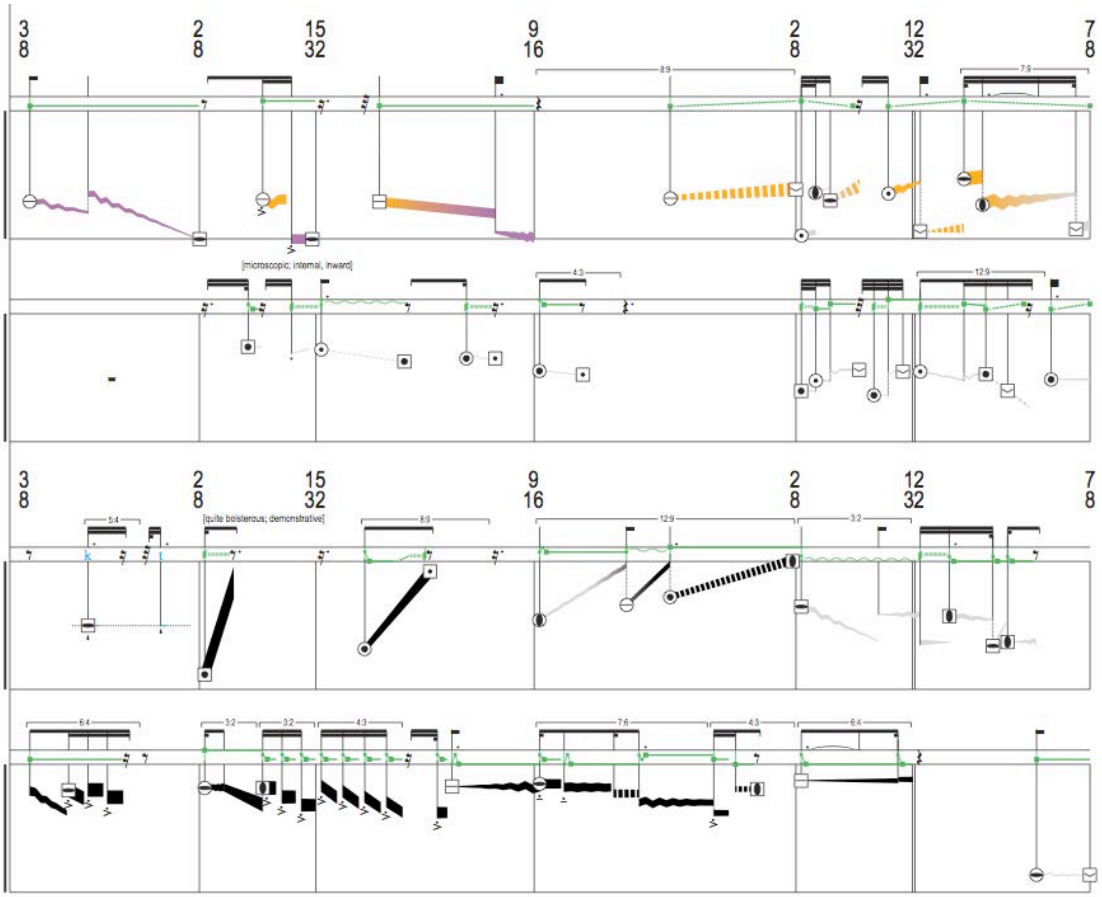
The second component of the notation is the tongue staff, which indicates the gestural activities of the tongue.[11] Four tongue positions are employed in the work, as shown in Example 19, moving from top to bottom and simultaneously from the front to the back of the mouth. As with the mouth shapes, ideally these positions should remain as defined and repeatable as possible, though it is of course understood that less physical space is available, fewer clear gradations are possible, and available tongue movements are largely contingent upon both mouth shape and glottis layers. These tongue positions combine with the prescribed mouth shapes to create a much wider range of vocalizations and vowel sounds than the rough reference vowels used to describe the shapes and positions would initially suggest. In their static forms, these combinations include various common umlauts as well as mouth/tongue positions used for harmonic/overtone singing, but in their unstable, transitional states (particularly when mouth shape and tongue position transition at independent rates), quite complex and unpredictable sounds emerge that could not be readily contained by even a much more complex and exhaustive notational system (such as the IPA, for example).

This staff also includes a range of symbols representing additional gestures including tongue position "trills," rolled r's, tongue position "grace notes" (quick movements from one position to another), and tongue position "mordents." The staff also includes indications of any pitched or unpitched consonants (notated in blue) that supersede the activities of the glottis and soft palate (these appear only in one of the three broader material types/behaviors in the work, generally connected to rhythmic unison events that construct composite sound structures consisting of combinations of attack, sustain, and cutoff sound events from multiple singers) (see Example 20).

[11] In earlier sketches for the notation of the work, this layer floated around the staff space similar to the way the green up-/down-bow indications moved in the notation in the quartet. In early rehearsals and development sessions, however, it became clear that having a fixed location for this information was easier for the singers, as they were able to trace the changes in tongue position through their peripheral vision with that information on its own staff.

	top, forward, touching the back of the teeth
	(as in the English vowel "ee")
	(as in the English vowel "eh")
	(as in the English vowel "ah")
	transitions between tongue positions are indicated with a dotted line

Example 19: Tongue position notation



Example 20: *A painter of figures in rooms*, Voices 5-8, mm. 57-62

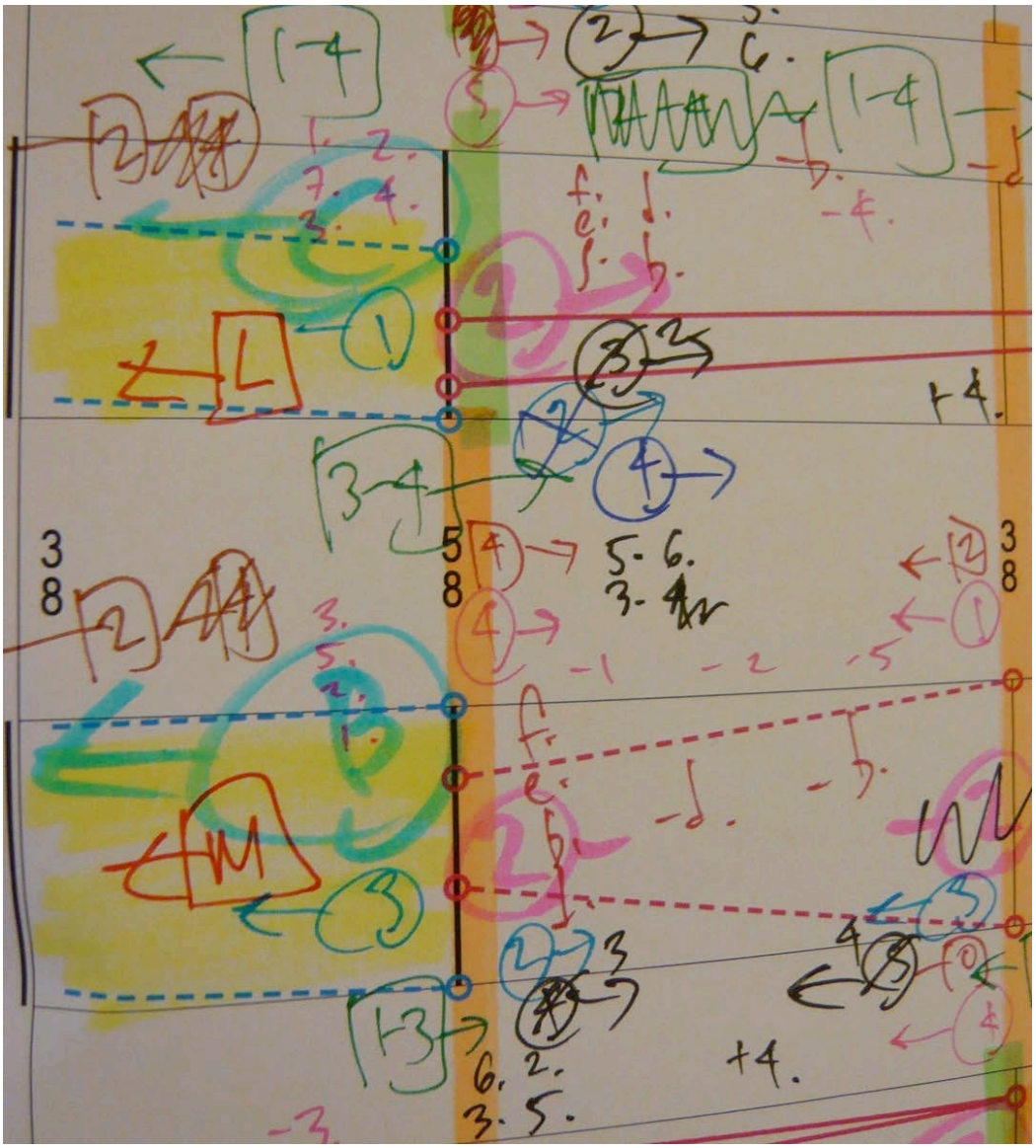
Gestural models, Movement spaces, and vocal implications

Much like the quartet, these various notational components are linked to movement spaces that are constricted and controlled, and, like the quartet, much of the soundworld of the piece emerges from unpredictable recombinations of gestures and movement spaces on several independent layers. For each of the physiological layers—vocal fold tension, air pressure, glottis position/tension, mouth shape, and tongue position—a similar system of spatial mapping occurs, moving from one available range of possible movements or positions to another for each phrase in the work.

Example 21 shows a fairly typical example from one of the many sketches developed during the compositional process, here demonstrating the multiplicity of constraint systems at work. Each of the colored numbers and letters is a stand-in for either an assigned number of gesture types or movement spaces, a specific designation of which gesture types are available (or are being added or removed from the available palette), or a particular behavior or tendency type for the phrase (determining particular modes of movement between disparate gestures). The pink and blue lines on the staff, both dotted and not (these indicate the three larger material types in the work), refer to the outer limits of the available vocal fold tension for that phrase.[12]

One of the broader implications that I have found most interesting is that this decoupled approach to the voice seems to reveal the particular uniqueness and personality of individual voices. It seems to me that this has precisely to do with the invisibility of the vocal mechanism. Unlike in string instruments, for example, where a certain amount of visual, physical modeling and mimicking is possible, with the voice, the training tends to be less explicitly physiological and more about imagined sounding results coupled with trial and error. The "planes" that are so central to the *Second String Quartet* simply do not exist in the case of the voice. Though there are of course schools of vocal training that aim to increase awareness of the physiological aspects of sound production, on the whole, in my experience, singers tend to start with an imagined sound and then adjust various bodily actions, components, tensions, etc., until the desired sound is achieved. Reversing this relationship—foregrounding the physiological and placing the sonic outcome in a position of uncertainty—has revealed a much more wildly diverse set of sounds and discrete vocal personalities. This approach has been useful as a way of breaking free from the "smoothing out" typical of much vocal training (and particularly choral training) in which those individualities are mitigated.

[12] There are in fact several additional layers of sketches with similar approaches to restriction and constraint systems that move from large scale mapping of form (tempo, meter, pulse, phrase groupings, etc.) all the way down to microscopic, gestural details.



Example 21: *A painter of figures in rooms*, sketch excerpt illustrating movement/gesture constraint mapping

This revelation of the uniqueness of each voice has been particularly apparent in the most challenging and awkward passages, ones that push at particular vocal extremities or that create unusual recombinations of physical states or movements. The "orange" glottis tension, for example (indicating extremely tight, gritty, rough, brittle pressure), revealed vast disparities between each of the singers of EXAUDI, the ensemble who commissioned and premiered the piece. It also revealed significant differences in how those singers understood their own vocal mechanism—their descriptions to one another of what a "tight" pressure was, from a physiological standpoint, varied dramatically. As such, the efforts of eight different singers to reproduce exactly the same notation with exactly the same set of instructions generate wildly different results, again particularly in the moments with greatest heterogeneity and stratification. This goes well beyond the unpredictability that exists in my earlier works, including the *Second String Quartet*. Much of the material of the piece rests on uncertainties once it moves from the abstraction of the constraint schemata and gestural modeling palettes into actual voices and actual physiologies. The differences between timbres and textures in various registers, the various breaks between those registers, the implications of various air pressures in those registers, combined with various positions and tensions of the glottis and the unique differences in mouth and tongue shapes between singers, all combine to create a highly unpredictable set of sounding results that reveal the particular vocal identity and personality of each singer.

This approach also aims to generate a much more immediate and raw vocalization, one that actively avoids the kind of self-aware, conditioned, and generally linguistic ways that we typically use our voices. The prioritization of vocalization as a physical phenomenon and the intentional reversal of typical "singerly" practice was, in effect, designed to *reveal* the voice rather than *use* the voice. By approaching the instrument as a set of spaces to be traversed, by setting up collisions and conflicts and resistances within those spaces, the goal was not a distanced, calculated, methodical neutrality, a kind of scientific tinkering, but in fact exactly the opposite. The goal was to remove the learned filtering of the voice, to strip away some of the mimicry that is central to our use of our voices, both in speech and song, in an effort at revealing a much more fundamental, bare, exposed expressive voice.[13]

[13] For more on this, see "Francis Bacon, a painter of figures in rooms," written as part of EXAUDI's 10th anniversary blog series, which, among other things, traces the entire process of learning and performing the piece. The text addresses the connection to the paintings of Bacon, focusing in particular on his depiction of mouths and bodies, and works as a particularly good companion piece to the more technical, procedural description of the work above. http://exaudi2012.wordpress.com/2012/07/07/francis-bacon-a-painter-of-figures-in-rooms/