

Writings on the Sound Canon

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Introduction

In this essay I explore the *sound canon*, a compositional device for new spatial and temporal interactions to emerge from a set of initial conditions. New methods of composing, including canons, have been moving beyond classical diatonic counterpoint for over a century, providing new ways of organising musical ideas and elements, with an increased focus on material content, such as: field recording, breaking apart instruments to surgically bring out their materiality, and new considerations of the performance space and the role of the audience. Owing to the sound canon's simplicity - a layering of the same recording at different playback speeds - the format accommodates a wide range of music: from noise music and musique concrète to diatonic counterpoint, depending on the base recording and its organisation over time. As I will show, the canon format has, in its harmonic form, strong overlaps with how sound behaves naturally, leading to a fractal organisation all the way down to the vibration of air molecules.

Similar to fugues, canons are strict organisations of leader (*dux*) and followers (*comes*) (Davidian, 2015); yet, there is a large variety of canon types, despite the intellectual challenge at hand. Its attraction for composer and listener may be found in a canon's potential to intimately relate musical object, phrase or theme to the underlying framework or texture of the composition; e.g. melody and harmony are closely linked in traditional canon forms, such as the round. Typically, each note or sound in a canon is connected to all the other parts, giving a sense of urgency to each moment in time. The experience is complex; what is heard in the present has a rational and often intelligible relation to past and future. Without accompaniment, a canon may act as a kind of closed system, an ecology of sound, as there are no external forces to shift the dominant key or influence dynamics. Despite a move away from tonality by (pre-)modernist composers, canon composition has seen a revival in the past few decades, which may be attributed to (1) the fact that canons can, in addition to melody and harmony, also act on the level of noise and (2) their relation to newer technologies, such as process music (Reich, 1968) and polytemporality in contemporary music more generally (Dobrian, 2012).

If we allow temporal shifts in addition to the speed change and we note that all waves can be decomposed into a bunch of sine waves, it can be argued that in fact all of mu-

sic is organised as sound canons, even a single note. For this reason, I find sound canon an appropriate name, since it brings the medium of sound to the surface of the composition.

This essay reflects on my own explorations with the sound canon; however, it is worthy of remark that the format is also at play in Annea Lockwood's sound installation *Jitterbug* (2007) and possibly in more. Lockwood's piece consists of two underwater recordings of the Danube at Grein that are played back in a gallery space over two speakers facing each other at some distance. The installation is rooted in the composer's sensitivity to the environment, resulting in exquisite field recordings and a clever setup for the performance with the audience immersed in the canon. This work is, to the best of my knowledge, the first example of what this essay denotes a sound canon. The speed differences between the water sounds lead to phasing, not unlike Steve Reich's tape experiments. In addition to explaining the sound canon, section 1 outlines this relation to Reich's phase music more formally and to other methods in composition, notably classical counterpoint and tempo-pitch connections in total serialism. Section 2 provides examples of sound canons, including audiovisual compositions.

1 The Sound Canon

This section introduces the formalism of the sound canon and discusses some of its inherent characteristics, challenges related to harmony and rhythm, and its relation to other compositional methods.

The *round* is the most simple and well-known canon. In a round the comms start at set time intervals, leading to harmony from voice crossings. Canon types depend on how the comms are derived from the dux via some transformation, known in music as *imitation*. For the *round* the imitation is the time interval; for the sound canon it is a stretching of the sound waves. Other imitations, such as transposition, inversion and augmentation, lead to their respective canon forms, most of which were developed in the Middle Ages, Renaissance and Baroque, resonating with religious and rational modes of thinking in art and philosophy during those and subsequent ages.

Traditional imitations in music are based on standard notation, such as inversion, interval, and augmentation. Some compositions are directly related to notation conventions, such as table canons¹. Arguably, contemporary music has become more and more concerned with materiality and hence with physics. John Luther Adams' statement, "What is music but audible physics?" (Adams, 2009) is, in light of the composer's strong ecological focus, indicative of this shift from mathematics to materiality and physics. Recording technology further contributes to this, as it allows sound to be captured as a physical object.

¹A Table Canon is constructed so that the same line is to be performed by two persons sitting at opposing positions (one of them is reading the same line upside down). An example can be found in J. S. Bach's *The Musical Offering*.

Reich's phase music; although often described as the mathematical process of phasing, is rooted in the materiality of tape and the physics of sound. As physics and mathematics overlap in science, so do materiality and order in music, which is also seen in serialism, as discussed below.

The imitation that underlines the sound canon is the time-stretching of a recording. As sound is a temporal medium, all its properties are affected by a change in playback speed, notably tempo and pitch. Ever since the invention of sound recording technology and the rise of *musique concrète*, alteration of playback speed has been a common effect and remains a basic feature in DJ sets (to link tracks) and digital audio workstations. Hence, it is quite possible sound canons have been composed without being recognised as such. To some extent, the sound canon may be thought of as a combination of the *prolation* (or *mensuration*) and *interval* canon. Not exactly, however, as other sound properties are also affected by the change in playback speed, for example timbre and how the sounds evolve over time. I adopted the name *sound canon*, since the canon is rooted in the properties of sound and has not been previously described in the literature to my knowledge, nor has it been used in a harmonic, or diatonic way.

1.1 Formalism

The imitation of the sound canon is the stretching of sound vibrations, so that the change in duration and pitch result from the same single operation. Importantly, the imitation of the sound canon is physical, rather than purely mathematical or rooted in music notation, such as the table canon.

Pitch is directly linked to the frequency of a sound wave, which is the number of pressure waves per second that pass through a medium (e.g. air); a melodic interval can be thought of as a change in that number. For example, when two voices sing a harmonic octave, one voice vibrates at twice the speed of the other. Similarly, when an audio track is slowed down, its frequency drops accordingly. It is useful to express this change in frequency or interval as a ratio, e.g. 1:2 for the octave. By altering the playback speed any pitch can be produced from any given one, limited only by the technology of the playback device. With digital means the possibilities are apparently endless, noting that different algorithms give different results, and in general the best results are achieved when speeding up, rather than slowing down. In case of slowing down, the digital file should have been recorded at a high sample rate to avoid digital artefacts ².

Annea Lockwood's *Jitterbug* (2007) is a 2-part sound canon based on an underwater recording of the Danube. It is perhaps the first example of a sound canon and Lockwood adopted a frequency ratio between the two recordings based on "what most pleased [her] rather than by anything more systematic or traditional in origin" (Lockwood, private

²Currently, audio recording at sample rates of 192kHz has become standard for most professional recorders, which for playback settings of 48kHz gives a 3 octave range before digital artefacts become audible.

conversation). In principle the sound canon could also support diatonic counterpoint, particularly with the octave interval ³.

Interestingly, integer frequency ratios, such as 1:2 and 2:3, have some advantages; they shift pitches on the harmonic scale and provide more traditional rhythms. The chromatic scale in Western music evolved from the harmonic scale, but is different to allow for key shifts. Harmonic scales are still in use, for example in Gamelan music. As a result, all intervals produced from simple integer differences other than the octave (1:2) are, strictly speaking, out of tune with respect to the equal tempered chromatic scale, though in some cases this is not audible for most humans. For example, an equal tempered perfect fifth-unison ratio is $2^{7/12} : 1 = 2.997 : 2$, which is very close to 3 : 2. The perfect fourth-unison ratio is $2^{5/12} : 1 = 4.005 : 3$, which is very close to 4 : 3. Therefore, the sound canon can form the basis of conventional diatonic music with a 1 : 2 ratio, or to good approximation with 2 : 3 and 3 : 4 ratios.

The relation between sound canon and phase canon becomes clear when considering a frequency ratio $n : n - 1$, with n sufficiently large for the pitch shift to be barely noticeable. This would give rise to the phenomenon of phasing, which will be more noticeable than the pitch shift for sufficiently large n .

The sound canon is rooted in the properties of sound, hence the name, which makes it unique among other canon forms, whilst having links with the prolation, interval, and phase canon. The most simple, diatonic sound canon uses an octave frequency ratio of 1:2. So for three voices such a canon can be schematised as shown in Figure 4. The first voice plays four times in the duration that the second plays twice and the third once. Such schemes (also known as *canoni*) may be used alongside the dux score, so that the score for the comes are redundant.



Figure 1: Example of a simple (fractal) scheme with 3 parts at octave ratios.

Performance of a sound canon is, strictly, only possible through recording and playback devices, or with instruments which string- or air column lengths are at appropriate ratios for the canon, as long as the physical connection is acknowledged somehow. That said, I

³Note values in standard notation have integer ratios, mostly of 1:2, such as crotchet versus quaver, quaver versus semiquaver, etc. except for triplets, which would be necessary for closer frequency ratios like 4:5 and 5:6 (or more complex time signatures).

believe in always allowing oneself to break rules; it is only for the purpose of this essay that this restriction is emphasised.

1.2 History of tempo and pitch relations in music

Throughout musical history, lower pitched instruments are generally assigned notes with longer duration. The relation between the duration of a note and its pitch is physical, practical, and has over time become the aesthetic norm in most musical genres. The bass part of a composition often serves to provide a basis for higher pitched melodies, which involve more grace notes and ornaments. This also holds for percussion, with a few exceptions; for example, Vinnie Paul's double kick drum in *Becoming* (1994) by Pantera. Additionally, it is simply easier to play quick passages on smaller instruments, and smaller instruments have higher pitch due to their smaller vibrational parts. It is noteworthy that many baroque composers experimented with rapid baselines (for example in the arabesques of J. S. Bach's *Goldberg Variations*, noting that its arias and genre pieces tend to have slower baselines).

In the postwar era of the 20th century there was a tendency among avant-garde composers to reject tonality. This eventually led to serialism, a concept characterised by giving equal weight to compositional elements (as opposed to having one key with a dominating scale). In addition to temporal and tonal patterns, sound too can be thought of as consisting of elements: amplitude, timbre, pitch, and duration (Cage, 1961). As such, total serialism aimed to deconstruct sound in order to reinvent music composition on the fundamental level of sound properties and giving equal importance to all its constituents.

Fourier and Helmholtz showed that periodic functions (including those describing sound) can be decomposed into sine waves (of varying amplitude and frequency). Technically, these can be included in a serialist organisation, but only when using artificial sounds (acoustic instrumentalists cannot, practically, decompose their sounds into pure sine waves). The idea of subjecting the decomposed sound objects to serial manipulation was proposed by Pierre Schaeffer, and used by Stockhausen in his *Studie I & II* (1953,1954). However, Messiaen's system of chromatic durations, used in his pre-serialist work *Mode de Valeurs* (1949-1950), is an even earlier example of a strict pitch-duration linkage in a composition. *Studie I & II* are organisations of the decomposed elements of sound (the sine waves), pitch, and duration (lower frequencies have longer duration and vice versa). The connection here is physical, as slowing down an audiotape (which is the material Stockhausen used) results in a pitch drop and extended duration of the notes. Later he translated these ideas to works outside the realm of electronic music, including the famous piece for three orchestras *Gruppen* (1955-57).

1.3 Traditional and avant-garde

The *sound canon* uses the same physical relationship between duration and pitch that was in fashion during total serialism. In the context of postwar modernism, characterised by separation and deconstruction, it is perhaps not surprising that the pitch-duration relation was never used for canon composition, which harks back to baroque times with an aesthetic that the avant-garde composers sought to reject. Instead, the linkage was there to emphasise differences between sound elements in order to express the totality of separate musical elements (Griffiths, 1995), as a metaphor for the conflicting and chaotic state of societies at the time. To find unity in the separated elements would have been contrary to their goals, particularly when this unity leads back to old forms of composition and aesthetic ideals, as the sound canon potentially does. Indeed, some prolation canons (developed in the 15th century and possibly earlier) can be performed as a sound canon, for example when the imitating follower is an octave down and plays at half the speed compared to the dux (see for example *Missa L'homme armé super voces musicales* by Josquin des Prez).

In addition to the overlap with serialism, the sound canon is related to process music and phase music, discussed by Reich in his essay *Music as a Gradual Process* (1968). In fact, all canons, except when accompanied, are arguably related to process music, including Reich's phase music. Reich was concerned with the intelligibility of the (gradual) process, hence his phase music typically adopts very small speed differences between two identical tracks or musical parts, so that one clearly hears the phasing: the gradual shifting out and back in of the tracks. Technically, this is not different from a standard prolation canon, be it that the tempo difference in phase music is unusually small so that many repetitions are needed to conclude a cycle. The tuning difference in Reich's tape works is subordinate to the ever evolving rhythmic qualities, since Reich used speed differences too small for the according pitch differences to be noticeable, much smaller than a semitone. Indeed, Reich was interested in the rhythmic shifts and gradual change of note or sound (including spoken word) meaning. In his subsequent phase compositions for acoustic instruments the pitch shift was discarded.

To conclude, the sound canon has a relation to works that explore strict pitch-duration linkage. Additionally, for very small frequency ratios the sound canon can mimic phase music; with larger, more systematically chosen ratios, such as 1:2, the sound canon becomes a traditional prolation / interval canon. Despite this fluidity, the sound canon is a form in its own right, since the imitation is a single act that can only be partly constructed from a combination of existing forms.

1.4 Audiovisual Composition

The moving image can be subjected to many of the imitative transformations used in music composition: time interval, augmentation (slow-motion), diminution (fast-motion), retrograde, or any combination of these. As in music, such devices change the expressive quality of the original material. Hence, layering the moving image imitations (either using multiple screens, split screens or opacity), along with the audio, would result in an audiovisual canon (with an audiovisual leader and audiovisual followers).

Light is, like sound, characterised by frequency. Hence, the imitation (stretching of waves) can be applied to colour too. However, the spectrum of visible light is approximately between 380nm (violet) to 750nm (red), which allows for only one ‘visual octave’. In terms of frequency, light is thus much more limiting for the composer compared to sound, which audible spectrum runs over approximately 8 octaves. For this reason, I have, so far, discarded the colour aspect of the audiovisual compositions. Another reason is that light (and human perception of it) is not physical in the same way as that of sound; we see strings vibrate slower for lower notes and we feel lower frequency pressure waves in our bodies. The bodily sensation from perceiving moving images is much clearer in the shapes and movement of visuals; that is, a change in colour is not perceptible as a change in frequency. Furthermore, when considering analogue technology, the colours of a film do not change along with the projector’s playback speed, whereas a change in the playback of audio tape does influence the pitch in addition to tempo.

Beyond frequency there are numerous relations between audio and visuals, as explored in Visual Music ever since the absolute films of the 1920s, see also Chion (1994). For example, the dynamics of a note, such as crescendo, is easily connected to an increase in light intensity; lowering pitches to an increase (or decrease) in size or position on the screen, and texture in visuals can be matched to texture in sound. *Canon* (1964) by Norman McLaren and Grant Munro explores some of these relations, where visuals illustrate a number of canon forms and the interactions between parts, which is animated or acted out to great effect. The visual expression from slow and fast motion can be utilised as an extra part of the composition, such as comedy in case of fast motion and drama with slow motion.

2 Compositions

This section explores a selection of sound canons. Some of the audiovisual examples originated from a desire to visually show the process, or to explore visual interactions like with sound. On-line links to the compositions are organised in Table 1.

2.1 3-Part Sound Canon for Recorded Violin

To illustrate the format of the sound canon I have filmed myself performing this piece ⁴, see Table 1 for the link. The choice of instrument, violin, is its visual transparency in how sound is produced, which the violin exposes with big movements (of the right arm and hand) contrasted against more delicate movements (in the left arm and hand). The canon has the character of an accompanied canon, with the lowest part changing the chord base, providing different emotional contexts for the same melody. It is not intended as an artistic piece to be exhibited outside the context of this essay. However, the resulting video is an effective audiovisual work for communicating the workings of this canon.



Figure 2: The dux of *3-Part Sound Canon for Recorded Violin*.

2.2 Electronic Movement

Electronic Movement is a 5-part sound canon and combines the 3:4 (perfect fourth) with 1:2 (octave) ratios. The 3:4 ratio makes the time-pitch canon harmonically complex, so the emphasis here is on rhythm and sound. The score with scheme (canoni) is shown in Figure 2.2, consisting of 4 bars with the same arpeggiated D chord (without thirds). For clarity the ratios of the parts are added; the leader (1:1) is the white square.

The fractal scheme or canoni is deconstructed in such a way that a small climax appears after 4 leader durations, before the main climax after 8 leader durations, when all parts end and start simultaneously. This moment is emphasised thanks to the crescendo, shown in Figure 3. With this scheme the temporal multiplicity allows the construction of a tension curve, without changing the performance of each part beyond their imitation.

2.3 Abstract animations

I have composed two abstract audiovisual canons: *5:4* (2015) and *3:2* (2016). In addition to 1:2 ratios (octaves), the canons have frequency ratios as per their title (5:4 - very close to major third) and (3:2 - nearly perfect fifth). In both cases, the audiovisual leader consists of a circle on a black background that performs a new movement whenever a new sound is played. The sounds were produced on a synthesiser (Minimoog Voyager). Both works have 4 followers, giving 5 audiovisual layers or objects. They start one after the other, allowing

⁴If you are a violinist wishing to perform this piece as part of this essay, please contact me (info@larskoens.com). I am evidently not a good violinist and incapable of bringing the composition to its full potential, so any help would be very much appreciated.

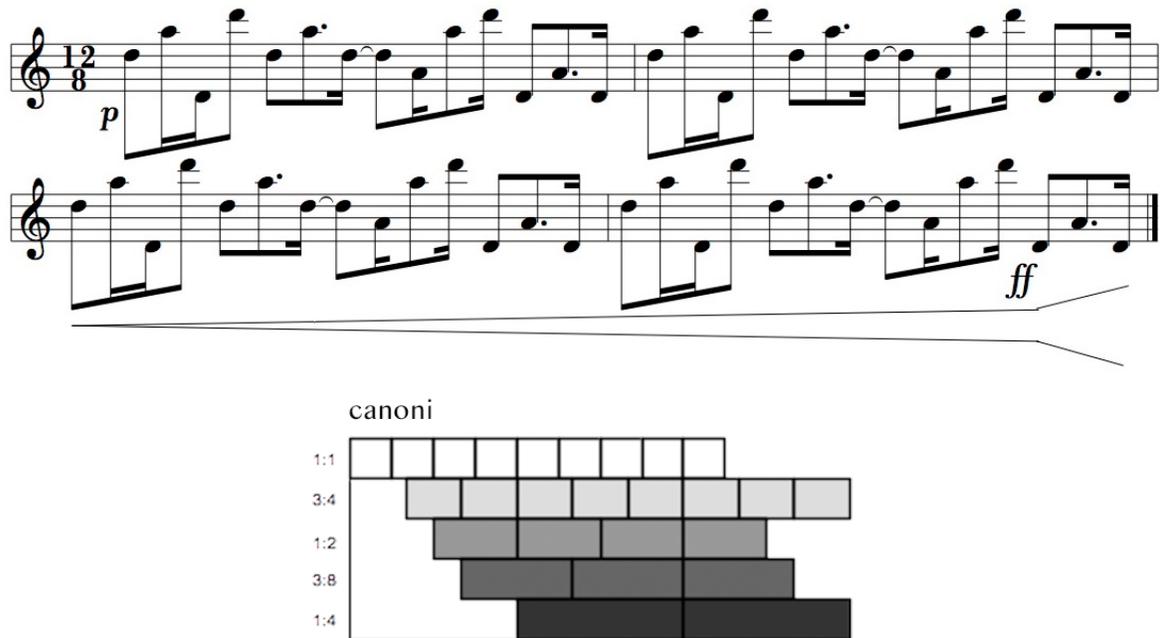


Figure 3: Electronic Movement with deconstructed fractal canoni.

the spectator to relate to a single part before experiencing interactions with subsequent parts. This is similar to the scheme of *Electronic Movement*, shown in Figure 3.

The films express very different emotions, due in large to the frequency ratio. In $5:4$ there is more tension, since the major third, when added, results in a tritone. This creates dissonances and avoids traditional tonality. Additionally, the polyrhythm of 5 against 4 is complex. On the other hand, $3:2$ is a harmonious interplay of sounds and images with a rhythm that features in many forms of dance music. The visuals of $3:2$ in particular appear aleatoric and hence playful, in line with the music; the circling movement in $5:4$ is more conceptualised to interact with the audio part.

In terms of style the works can be related to Visual Music. However, contemporary Visual Music has been concerned with technical animation abilities to the point where many such works are impressive showcases of the maker's skills. That is, the animation skills on display in $5:4$ and $3:2$ may be disappointing for the Visual Music fan. Most Visual Music practitioners are in fact animators, not audiovisual composers. Contrary to this trend in Visual Music, $5:4$ and $3:2$ are works based on "audiovisual objects", in the sense that sound and image respond to the same transformations, resulting in a relation from within the format, rather than translations between music and visuals through separate

operations on image and sound.

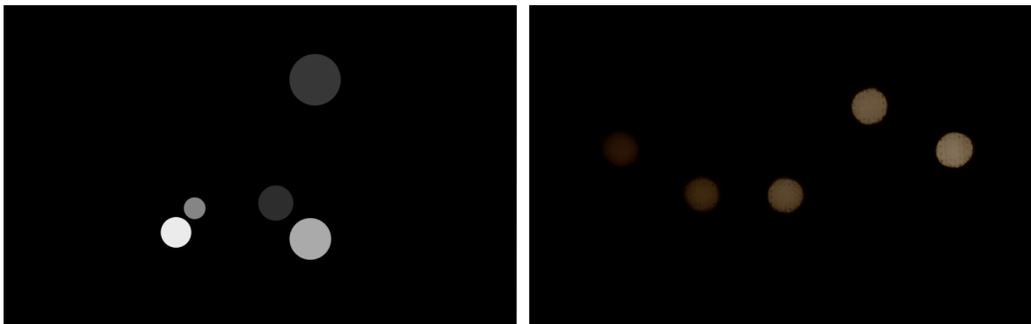


Figure 4: Stills from $5:4$ (left) and $3:2$ (right).

2.4 Total Commitment

Total Commitment is the first sound canon where I used archival footage, see Figure 5. In comparison to the abstract animations, the change in playback speed is much more apparent, because it distorts our normal experience of time. Altering the playback speed is a common filmic device to add drama or comedy.

The archival footage used for *Total Commitment* is Leni Riefenstahl's *Fest der Schönheit* (1938), downloaded from archive.org from an upload by iconauto2 under a public domain licence. I extracted parts where I felt the divers resemble flying warplanes or bombs, which was also expressed through sound. The iconic images of Leni Riefenstahl's documentaries are stained by the political context of nazi Germany. Riefenstahl's artistry, expertise and dedication to the filmmaking process result in a beauty that is groundbreaking yet uncomfortable due to the historical context. *Total Commitment* expresses the discomfort of this beauty by restructuring the olympic diving footage into a multi-screen format that juxtaposes the footage against itself and, through sound, against the historical context of her films.

However, it is not my intention to make any moral judgements or political statements; I simply aimed to express the way in which I experience the original film and finding a new aesthetic from this. Some filmmakers working with archival material carefully consider the historical context and aim to present the material truthfully. I believe this is impossible, due to problems related to historicity. Instead, *Total Commitment* is a creative treatment of historically complex archival footage with contemporary audiovisual effects.

The base compositional structure is the same as that of *3-Part Sound Canon for Recorded Violin*. However, the visuals interact more strikingly with each other by choosing certain time intervals between movement and still images. The audio closely follows the movement and pauses of the visuals, albeit not strictly, such as with reverbs and drones extending over the still images. The time intervals between moving- and still image in

Total Commitment were chosen so that the structure of the sound canon is part of the structure of the dux.⁵

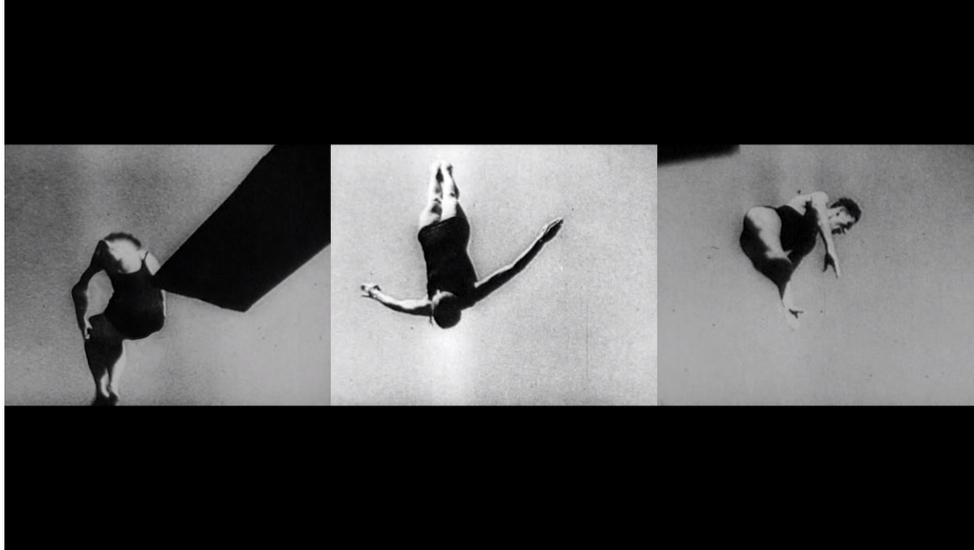


Figure 5: A still from *Total Commitment* (2019).

3 Conclusion

This essay acknowledges the sound canon as a compositional form that bridges sound and tonal composition in recorded media. It has overlap with traditional forms of music composition (prolation and interval canons), the postwar tempo-pitch experiments in musique concrète laboratories, music as process, and the phase canon. Evidently, the character of a piece of music is influenced by the compositional structure; yet, the canon format allows for significant diversity, which I hope is evident from the works discussed.

Given the plethora of 20th and 21st century compositions that explore playback speed alterations it is hard to state with certainty that Annea Lockwood's *Jitterbug* (2007) is indeed the first sound canon. As explained, Steve Reich's tape works can be described as sound canons too, despite being commonly classified as phase music (an acknowledged canon type without mention, however, of the pitch changes as this was not Reich's focus). The works I discussed here often use more traditional harmonies and rhythms, showing for the first time that harmonic (even diatonic) counterpoint is possible from the layering of

⁵This fractal feature is common in prolation canon composition. For example, consider a simple 2-part prolation canon. If the two voices are to play in unison in some part of the composition, then part of the dux needs to be an augmented copy of itself.

| Composition | Link |
|---|---|
| <i>3-Part Sound Canon for recorded violin</i> | vimeo.com/289963817 |
| <i>Electronic Movement</i> | soundcloud.com/larskoens/electronic-movement |
| <i>5:4</i> | vimeo.com/119754060 |
| <i>3:2</i> | vimeo.com/155966948 |
| <i>Total Commitment</i> | www.edfilmfest.org.uk/2019/total-commitment |

Table 1: Links to compositions.

playback speeds. I have extended this canon format to the audiovisual domain to explore the temporal juxtapositions of audiovisual material. Importantly, the abstract works have a relation in style to Visual Music, but these compositions did not arise from translations between sound and image; they stem from the desire to connect sound and moving-image into an audiovisual object.

Having written a number of canons, I believe that one obtains an intuition for taking the first steps. With the right start, a canon writes itself; if not, the process becomes overly difficult often without satisfactory results. A good canon enhances the listener’s experience of the presence, giving it urgency, arguably unlike any other method of composition. It challenges our very idea of what is meant by the ‘present’, the ‘now’, as the listener is simultaneously confronted with what was and what is yet to come.

Using the sound canon for harmonic or diatonic counterpoint composition is challenging, due to the high amount of symmetry as was outlined with fractal canoni. Yet, these challenges are balanced by surprising interactions between the composition’s elements. The interaction between the format and me as composer is a fruitful creative process that will hopefully lead to more work and other ideas, possibly beyond the sound canon.

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