

GOLDEN SECTION PROPORTIONALITY IN THE MUSIC OF dZIHAN & KAMIEN

— FEATURE ARTICLE —

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ABSTRACT

Academic studies of the golden section are evidenced across a range of disciplines. In music the discourse has been dominated by analytical studies from the realm of classical music but much less with relation to popular music. In order to explore this absence an in-depth case study was undertaken into the golden section within EDM through an analysis of the musical output of the European duo, dZihan & Kamien. The authors employed time-based rather than conventional score-based analytical procedures, that is, through counting elapsed recorded musical time. Key musical event points relating to compositional structure provided criteria against which calculations were made, while the deviation of musical event points from the mathematically calculated golden section points was also evaluated. From some 66 tracks by dZihan & Kamien analysed, 45 demonstrated less than just 3.5 percent deviation from calculated golden section points.

KEYWORDS: golden section, EDM, musical proportion, digital composition

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INTRODUCTION

The history and influence of what is known as the *golden section* within human thinking and upon human creativity reaches back to Euclid in the fourth century BC and reappears in differing terminologies—golden section, golden ratio, golden mean, divine proportion—throughout Western thought since. Understood as a measure of proportionality and balance, the golden section, in purely geometric terms, occurs when a line or distance is divided in such a way that the ratio between the lesser [B] and greater [A] lengths is equivalent to the ratio of the greater length [A] to the whole [C], which can be expressed as $A:B = C:A$. Put numerically, if the whole is a single unit, then the value of the larger length is 0.618 and the lesser 0.382. Expressed as a percentage the golden section of a distance or length occurs at a point corresponding to 61.8 percent of the whole.

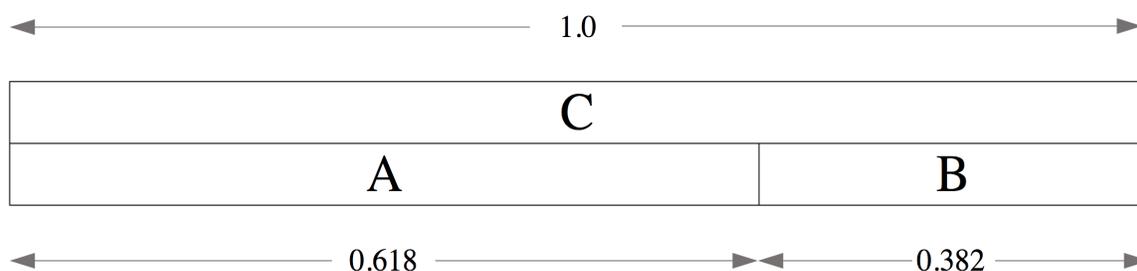


FIGURE 1. GEOMETRY OF THE GOLDEN SECTION

This ratio or proportion based on irrational numbers has been conjectured as a mathematical principle not only reflecting universal laws like the structure of DNA, the growth patterns of plants, the shape of seashells and the spiral structures of galaxies.¹ It is said to be also embedded in the products of human creativity such as architecture, graphic design, product design and so on.² Alongside this extensive literature from within the visual arts, there also exists a body of scholarship regarding the golden section and its relationship to music, primarily with respect to notions of structural balance and proportion.

THE GOLDEN SECTION AND MUSIC

The relationship of the golden section to music dates back to the nineteenth century with Zeising's 1854 landmark book "New Theory of the Proportions of the Human Body" where he argued the case for establishing universal laws of beauty—encapsulated in the golden section—which would correspond to observable patterns in nature and art.³ However, the main growth of serious scholarship in the realm of music and the golden section began in the late twentieth century and as Michelle Phillips has pointed out, "from 1970 to the

present day, the number of publications that mention the golden section has increased each decade” (Phillips 2019: 3), primarily exemplified in the work of scholars such as Ernest Lendvai and Roy Howat.⁴ To a lesser extent, the creative output of other composers in relation to the golden section has been explored by a diverse range of studies that include musical works spanning some seven hundred years.⁵

In very much the same way that golden section proportionality in the visual arts has been calculated through the counting of lengths or distance, the analytical procedures in these music-based studies have been implemented through the horizontal arithmetical counting of the notation of barlines, pulse and individual notes throughout the score of a particular piece.

DETERMINING GOLDEN SECTION EVENT POINTS IN MUSIC

The analytical procedures within the literature cited above employ a wide range of musical factors to determine what are called later in this study “golden section event points”. In essence, event points occur when the musicologist uses particular musical parameters in a proportional analysis of a chosen piece of music; these may be dynamics, pitch, harmony, tempo, instrumentation and timbre, or a combination of more than one parameter. Some criteria used in studies have included changes of key, musical pauses, a return to the tonic key, the introduction of new themes and so on. What is clear is that a very diverse selection of music elements have been used by analysts across a range of classical music to enable their calculations of golden section (GS) event points, ranging from small scale musical pieces such as Howat’s analysis of Debussy’s five minute long *Jardins sous la pluie* for piano to larger scale works such as Lendvai’s study of Bartók’s three movement *Sonata for Two Pianos and Percussion* at around twenty six minutes (Howat 1993: 136-38; Lendvai 1996: 18-26).

PROPORTIONAL DEVIATION

Of course, in any numerically based analysis of a piece of music some consideration needs to be paid to what degree of mathematical deviation from the golden section ratio can be regarded as meaningful. In this respect Adams makes the following important observation:

For the analyst who seeks any kind of credibility in claiming the use of GS in a work, it is crucial to minimize the extent of acceptable deviation from the exact GS ratio. After all, GS proportions are perilously close to one-third and two-thirds, fundamental divisions in music. Slightly overshooting the first or undershooting the second can easily bring the composer into the purview of GS” (Adams 2003: 243-44).

He goes on to suggest that a reasonable margin might be 2 percent. Atlas, in discussing the potentiality for contradictions of golden section points when the music is being performed, points out in his scrutiny of recordings of Puccini aria from *La Bohème* that these range from 1.6% to 2.66% (Atlas 2003: 277). Rofe, in his analysis of the golden section in the music of Shostakovitch, employs an accuracy margin of plus/minus 1.5 percent (Rofe 2008: 32).

THE GOLDEN SECTION AND NON-CLASSICAL MUSICS

As can be seen, the studies outlined above have been concerned with the golden section in Western classical music spanning a time period of at least six centuries and a wide range of styles from early mediaeval choral music to opera and twentieth century electronic music. And within the broad spectrum of what constitutes classical music there have been a lesser number of studies in other genres such as *musique concrète* and electroacoustic music.⁶ There is a paucity of published papers on the golden section in the similarly wide stylistic field of popular music; thus this study seeks to explore possible golden section proportionality within popular instrumental music, specifically electronic dance music (EDM), doing this through the work of European duo dZihan & Kamien.⁷

THE MUSIC OF DZIHAN & KAMIEN

dZihan & Kamien's music is broadly characterized by a blend of instrumental jazz and electronic idioms fused by layers of acoustic and synthetic parts, often with an emphasis on near-Eastern modes in the lead lines. In terms of genre, their work straddles downtempo, nu-jazz and acid jazz with prominent traits of house, funk and soul. Tracks are largely instrumental and range in duration from around two to eight minutes. Instrumentation typically comprises drums or percussion, bass and keys, over which a range of different instruments carry the lead lines, often using near-Eastern modes and instruments with free improvisation. There is also extensive use of sampling, editing and looping techniques throughout, indicating the use of contemporary digital audio workstation (DAW) software tools. This is further evidenced by each track having a consistent tempo, suggesting the use of a grid-based timeline to record and/or sequence the tracks.⁸ In terms of compositional form, their music largely aligns with contemporary electronica idioms. Percussion is in a simple quadruple meter at a regular tempo over which thematic material is introduced and repeated (looped) with some variation. And development is not established through change of key, tempo or introduction of contrasting movements, but through variation in the combination of different instrument parts. Typically, a predominant theme is established, followed by contrasting instrumental and/or breakdown sections, and finally a return to the original theme.

STRUCTURE IN THE MUSIC OF DZIHAN & KAMIEN

Whilst tracks from the third studio album, their 2009 *Music Matters*, are more pop-oriented, relatively short (mean duration 3'46") and utilize a typical verse-chorus song form to provide a sense of unity throughout the song, the most prevalent characteristics of dZihan & Kamien's work can be found in the studio albums *Freaks & Icons* (2000), *Gran Riserva* (2002) and *Lost and Found* (2010). These are more representative of EDM form, combining and varying loop-based layers of instrument parts to articulate the development of a single musical theme, with most tracks lasting between four and six minutes (mean duration 5'05"). Here, the main theme provides a sense of unity across the track, while

significant changes to instrumentation and dynamics in the breakdowns provide the main source of musical, sonic and dynamic contrast.

EDM FORM IN dZIHAN & KAMIEN'S WORK

At this point, it should be made clear that it is inaccurate to define dZihan & Kamien's music *wholly* as EDM, since musical content and instrumentation identify more clearly with jazz, funk and middle eastern styles. Furthermore, the majority of their work has an emphasis on acoustic instruments played by real musicians as opposed to electronic sounds controlled by computer sequencers. However, their work *is* representative of the loop-based production paradigm allied to contemporary EDM that essentially manipulates one musical idea across a whole composition through different combinations of looped instrument parts.

Whilst it serves as a relatively primitive overview, not being representative of the nuanced and divergent nature of contemporary EDM, DJ Stanley's "song map" does provide a useful framework of reference for the analysis of how musical materials are structured through time, and it continues to appear in the literature to illustrate the rudiments of EDM form (Butler 2006: 222).⁹

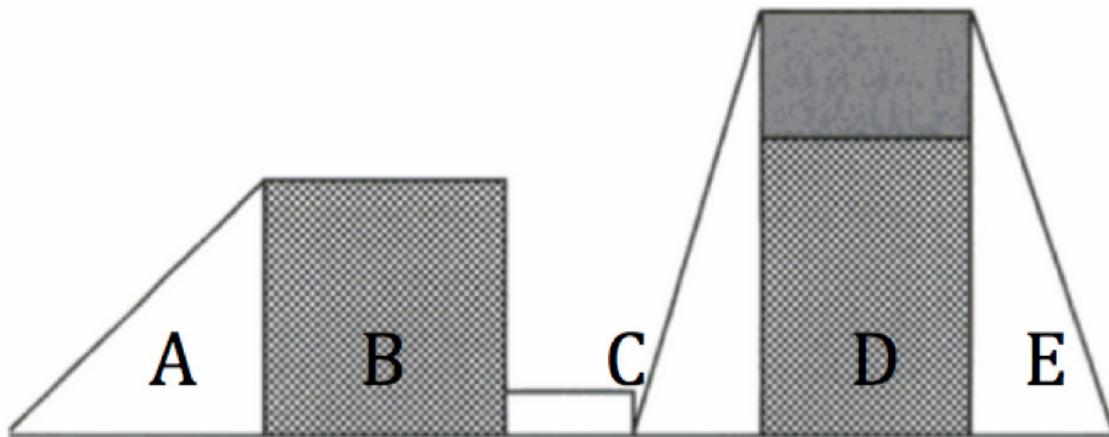


FIGURE 2. SONG MAP FOR EDM FORM

This model communicates not only the order of sections through time (x -axis), but also the emergent arc of dynamic intensity (y -axis). Thus, the width of any given region indicates its duration as a scaled proportion of the whole track, whilst vertical height represents an aggregated measure of the amplitude, instrumental complexity and overall energy presented by that section. The above literature is largely consistent in its identification of the different sections.

A	Lead-in / Intro	establishes feel, builds up to the core
B	Core	main thematic material introduced & developed
C	Breakdown	majority of instruments muted, ambient feel, builds to drop
D	'Drop' & Core	max intensity, to reintroduce main thematic material
E	Lead-out / Outro	gradually drops away to finish the track

FIGURE 3. STRUCTURE OF EDM FORM

The *core* can be thought of as the foremost section of the piece that carries the main theme at its highest intensity. It is described as the “fullest” section (Anderson & Eigenfeldt 2011: 9). All instruments and loop layers are usually “thicker” and “simultaneously active” (López-Serrano et al. 2016: 503). Meanwhile, underpinning bass and percussion provide the track’s “regular groove” (Solberg 2014: 73). Looking at DJ Stanley’s song map, it can be seen that the core sections (labelled B and D) establish the main material at the highest intensity around which the other sections are arranged.

The *breakdown* denotes a distinct section within the track that performs two important functions. Firstly, it contrasts with the preceding core section (B) which is often highly repetitive and thus susceptible to becoming stale. Secondly, it builds emotional tension and heightens musical anticipation towards the reintroduction of the core (D) at a key point referred to as the drop, and in doing so renders the final core section more powerful. Thus, it can be seen that the function of the breakdown is as “a contrasting section to the verse...to build tension, and lead back or crescendo to the verse in anticipation of ‘the drop’” (Anderson and Eigenfeldt 2011: 9).

The *drop* occurs when the breakdown ends and the final core section begins; to reference the earlier song map, this is the point at which C transitions to D. This moment is interpreted as the “culmination of the track” (Solberg & Jensenius 2017: 308). It is the “tension-resolving part” which Solberg describes as the highest intensity point of the composition (Solberg 2014: 68-70). This could be understood as the pivotal moment of the composition that elicits a “heightened and intensified emotional experience” in the listener through the careful construction of the preceding breakdown section (Solberg 2014: 74).

Within the context of this broad EDM structure, the authors had noted (informally in the first instance) some particular resonance with the golden section in the music of dZihan & Kamien, which consequently provided the impetus to examine their music in more detail. Furthermore, given the substantial and varied musical output of the duo, with over 50 tracks incorporating elements of downtempo, trip-hop, house and other loop-based EDM sub-genres, the focus on dZihan & Kamien’s repertoire provided a breadth and diversity of examples. As a result a more in depth and detailed study of the whole of their output was undertaken.

Initial observations seemed to show that the point of golden section in dZihan & Kamien's tracks often coincided with the start or end of breakdown or instrumental sections, while more extensive listening also pointed towards middle-eight and bridge sections as being potentially prominent. Significantly, this shaped the overall approach towards determining golden section event points in the study; that is to say, it focussed the analysis upon the boundaries of these key sections that demarcated their start and end points, which are now referred to as *sectional boundary points*. Consequently, the function and importance of these sections within their respective compositional wholes was considered, which necessitated an interpretation of each track's overall structure and how it was organized through the ordering of sub-sections across the timeline.

What unified these sectional boundary points in terms of function was that they marked the junctures at which significant musical changes occurred. For example, the end of an instrumental section might transition into the start of a breakdown, or the breakdown back to the core. Furthermore, these boundary points often expressed the composers' decision to introduce *contrast* through new musical layers and significant changes to instrumentation and dynamics. In the case of the breakdown and instrumental sections, quite often their end points actually represented what could be considered the pinnacle of the piece, where dynamic intensity built towards the drop and a final reprise of the core. The significance of the sections themselves was also intimated by their uniqueness and prominence, since the breakdown and instrumental sections often only occurred once in the track and were emphasized by extended duration, variation in instrumentation, significant dynamic changes and sonic manipulation. Collectively, these criteria reinforced an approach towards determining sectional boundary points as meaningful golden section event points, and as a result, the analysis was predicated on the significance of these sections within the overall compositional structure.

MATERIALS AND METHODS

Accessing dZihan & Kamien's catalogue of work was a relatively straightforward process. Using *Discogs* as a database of all official releases, it was possible to source physical CDs and to access individual tracks using online streaming services (Spotify and YouTube). To arrive at a definitive list of recordings for use in this study, it was firstly necessary to filter out duplicated releases, radio edits of longer tracks and remixes by other artists. This left 67 tracks. By taking a proportional sample from this list, a comprehensive exploration of the prevalence of the golden section within their music then became feasible.

The challenge of course would be to implement the predominant methodology of counting from a musical score, which has formed the backbone of all previous golden section studies in musical composition. However, since dZihan & Kamien's mode of music creation is through DAW-based software tools, any analysis cannot be contingent upon counting from a musical score. Similarly, since the tempi in all the analysed tracks remain consistent, issues of performance variation impacting upon score-based analysis are irrelevant. Score-

based counting was jettisoned and replaced with a temporally-oriented (elapsed, or linear time) methodology of counting fixed musical recordings of tracks in minutes and seconds.

This time-based analytical procedure was then used to calculate the golden section point for each track, where the total duration of a track was independently measured, converted into seconds and multiplied by the golden section constant (0.618).¹⁰ So, for example, the mathematically derived golden section point—hereafter referred to as the calculated GS point—for *Ocean Air* (2000, duration 5'20" or 320 seconds) was calculated to occur at 3'18" (198 seconds) as follows: GS point = 320 secs * 0.618 = 198 secs = 3'18".

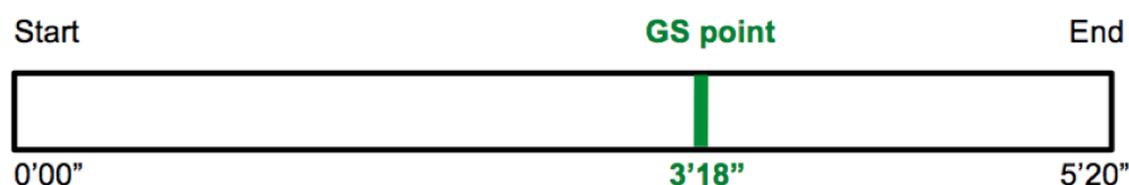


FIGURE 4. DERIVING THE MATHEMATICALLY CALCULATED GOLDEN SECTION (GS) POINT. THE CALCULATED

Following the GS point calculation, a structural analysis was undertaken for each piece by listening through in real-time from beginning to end, taking note of the order, duration and organisation of the different musical sections, the instrumental arrangement and any prevalent dynamic changes. In essence, the aim was to establish an overview of each composition's structure, to enable informed judgments to be made about the calculated GS point in the context of the whole composition. An example of this structural overview is shown below, using *Ocean Air* (2000) to illustrate.

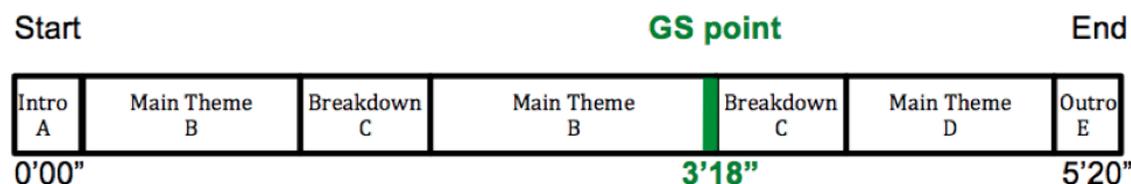


FIGURE 5. OCEAN AIR (2000) DUR. 5'20" SIMPLIFIED STRUCTURAL OVERVIEW

The calculated GS point was then reviewed to ascertain whether any significant musical events coincided with its intersection. In the example above, it can be seen that the calculated GS seems to occur close to the sectional boundary point between the main theme and the breakdown, and so this would be noted and scrutinized further.

TEMPORAL DEVIATION

When determining whether a track supported any coincidence between the calculated GS point and an identified musical event point, any such musical events are unlikely to occur at the *exact* timing of the calculated GS, and, reflecting the literature's reference to acceptable deviation, a figure of +/-3.5 percent was implemented in order to determine whether any such musical event was indeed close enough to be permissible. This also took into account Adams' concerns that GS proportions are "perilously close" to the common divisions in musical structure of one-third/two-thirds (Adams 1996: 243). The acceptable deviation—which will now be referred to as the *Deviation percentage*—was calculated as follows: $\text{Deviation} = (\text{GS point} - \text{Musical Event}) / \text{Total Track Duration}$.

To illustrate this in *Ocean Air*, the GS point of 3'18" (198 seconds) is just two seconds away from the start of the breakdown at 3'20" (200 seconds). Dividing this time difference by the track's total duration of 5'20" (320 seconds) results in a deviation percentage of -0.625 percent. Since this figure is within the threshold of +/-3.5 percent this was considered as close enough to the GS point to be deemed coincident. Had the deviation percentage been beyond the value of +/-3.5 percent it would have been rejected.¹¹

RESULTS

Applying this methodology across all 67 of dZihan & Kamien's tracks, 22 were excluded from further analysis for the following reasons: one was inaccessible (*Sammy Fu* vinyl-only release); seven had no significant musical event points at the calculated GS point and fourteen had musical event points with greater than a 3.5 percent deviation. The remaining forty-five tracks were found to support coincidence of the calculated GS point with key musical event points, within the threshold of 3.5 percent deviation. The most significant initial observation was that the calculated GS point of a large proportion of tracks appeared to coincide with the start or end of key musical passages, most commonly the breakdown but also instrumental and bridge sections. Beyond this, there were other occurrences where the calculated GS point coincided with more unique musical event points such as the holistic division of a track into separate proportions.¹² The inverse GS point was also considered, leading to further instances of coincidence against key musical event points.¹³ Consequently, it was possible to establish three clear event categories that brought all these examples together in a structured overview of how and where the calculated GS points coincided with musical event points for dZihan & Kamien's tracks.

Event Type 1	Marks <i>start</i> of key musical section*	n = 21
Event Type 2	Marks <i>end</i> of key musical section*	n = 12
Event Type 3	Marks <i>other</i> significant musical section	n = 2
	Coincidence based on 0.382 (<i>inverse</i>) GS point	n = 7
	Marks <i>start</i> of ramp event	n = 3

* key musical section = breakdown, instrumental or bridge

FIGURE 6. GOLDEN SECTION EVENT TYPE CATEGORIES

To clarify, an overview of the whole data collection process is presented in the diagram below.

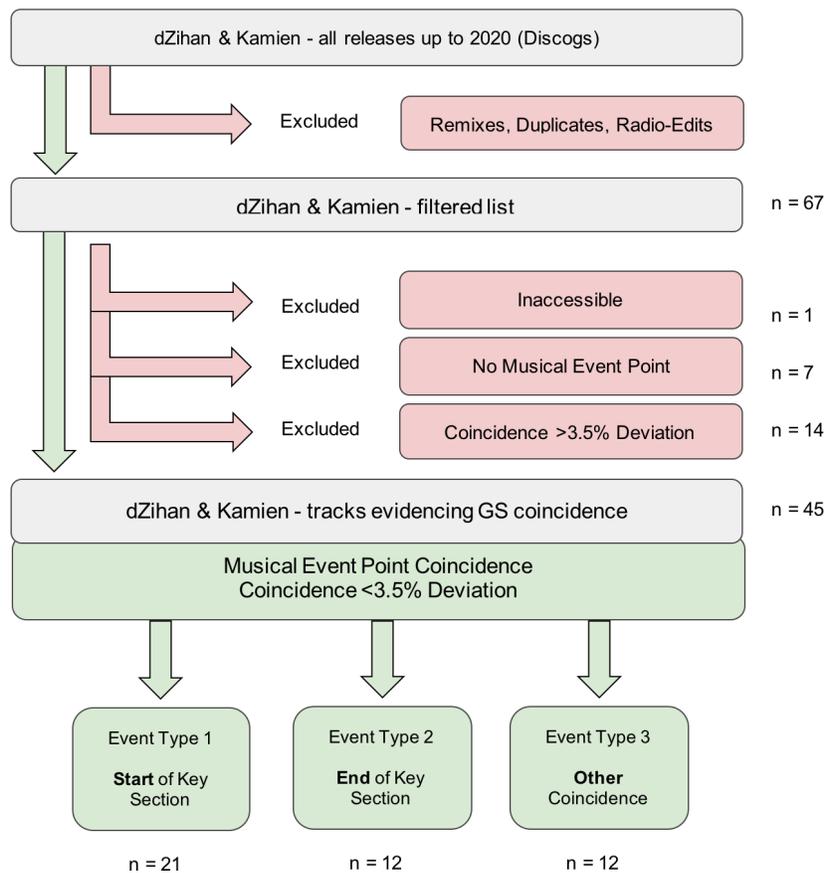


FIGURE 7. OVERVIEW OF DATA COLLECTION PROCESS

AN ANALYSIS OF dZIHAN & KAMIEN'S MUSIC THROUGH THE EVENT TYPES

EVENT TYPE ONE (TWENTY-ONE TRACKS)

This event group brought together all instances where the calculated GS point coincided with the start of a key section within the composition. Of the 21 tracks included, ten coincided with the start of the main breakdown, four coincided with the start of a break, four coincided with the start of an instrumental and three coincided with the start of a bridge.

Event type one: start of key section					
Track	Duration	Calculated GS Point Time	Musical Event Point Type	Musical Event Point Start Time	Deviation %
Weltempfanger	04:24	02:43	Breakdown Start	02:44	+0.38%
Ocean Air	05:20	03:18	Breakdown Start	03:20	+0.63%
Unknwn	04:46	02:57	Breakdown Start	02:55	-0.70%
Arabesq	05:14	03:14	Breakdown Start	03:17	+0.96%
I Guess She..	04:13	02:36	Breakdown Start	02:39	+1.12%
Mojamore	04:04	02:31	Breakdown Start	02:34	+1.23%
Homebase	07:12	04:27	Breakdown Start	04:33	+1.39%
Noon	06:05	03:46	Breakdown Start	03:39	-1.92%
Thrill	04:43	02:55	Breakdown Start	02:46	-3.18%
Satellite Tank	06:51	04:14	Breakdown Start	04:27	+3.17%
Just You & I	05:52	03:38	Break Start	03:40	+0.57%
Gutenm'duft	04:34	02:49	Break Start	02:54	+1.82%
1	02:17	01:25	Break Start	01:28	+2.19%
99	03:10	01:57	Break Start	01:52	-2.63%
Dundaeova	04:19	02:40	Instrumental Start	02:41	+0.39%
Call Me	04:51	03:00	Instrumental Start	03:03	+1.03%
Ahmet Bont	05:31	03:25	Instrumental Start	03:32	+2.11%
Join Us	3:49	2:22	Instrumental Start	2:15	-3.1%
Summer Fever	04:14	02:37	Bridge Start	02:38	-0.39%
Busted	03:43	02:18	Bridge Start	02:16	-0.90%
Life Can Be Good	03:40	02:16	Bridge Start	02:14	+0.91%

FIGURE 8. EVENT TYPE ONE DATASET

The start of the breakdown was by far the most common musical event to coincide with the calculated GS point in this event category, accounting for ten of the twenty-one tracks. Whilst each track's breakdown varied in terms of duration, common to all these instances was the section's role within each track, clearly demonstrating the defining features identified in the previous discussion of the breakdown and EDM form (introduction of contrasting material, reduction in dynamic intensity, removal of key percussive elements such as kick drum and lead towards the drop and a reprise of the core).

For example, in *I Guess She...* (2000) thematic material is introduced and developed through the intro up to 1'29", after which the fullest combination of instrumental layers, representing the core, plays until 2'04". The track drops in intensity through an instrumental section to lead into the breakdown at 2'39", which in this example starts three seconds after the GS point (deviation of 1.12 percent). The majority of the instrument parts, including the primary percussive layers, are removed during the first half of the breakdown, leaving just the vocal sample "I guess she fell in love" playing over sustained electric piano, muted kick and hi-hat; this is a unique combination of instrument layers in the context of the whole composition. Use of reverb and delay create a sense of ambience and space that complements the significant drop in dynamic intensity. The second half of the breakdown introduces percussive layers to build intensity towards the drop where the core is reintroduced at 3'10" and continues into the outro and the end of the track.

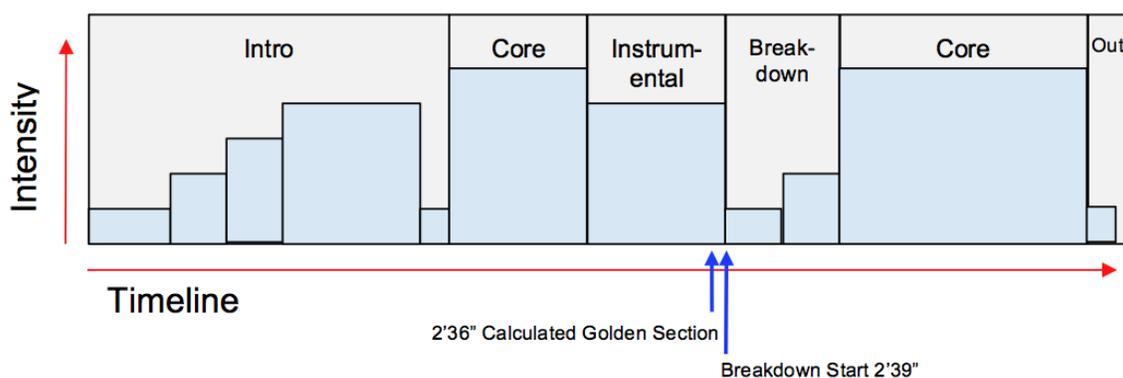


FIGURE 9. *I GUESS SHE...* (2000) DUR. 4'13"

The other nine tracks in which the golden section coincided with the start of the breakdown bore similar characteristics; the calculated GS point marked the transition from a prior, busier and more intense section—most often the core—to a more ambient or sparse section with muted percussion and attenuated dynamic intensity.

Four further examples—*Just You and I* (2000), *Gutenmorgenduft* (2002), *I* (2010) and *99* (2020)—also evidenced coincidence at the start of breakdowns. However, there were some differences in the defining features of these sections. For example, they were of significantly shorter duration, or they existed in relation to another more prominent breakdown section

elsewhere in the track that led us to differentiate these instead as break sections, in order to remain true to the defining features of the breakdown in EDM form.¹⁴ Nevertheless, they did appear to serve a similar purpose, in that the calculated GS point would coincide with the start of a break section in which instruments would thin out, percussion would be removed and intensity would diminish, before returning to the core.

The other examples in this event group indicated close coincidence of the calculated GS point with the start of an instrumental—*Dundaeova* (2002), *Call Me* (2010), *Ahmet Bont* (2010) and *Join Us* (2010)—or bridge section—*Summer Fever* (2005), *Busted* (2005), *Life Can Be Good* (2005). These could be considered as musical event points since they evidenced the composers' intention to introduce contrasting musical materials at a clear sectional boundary point.

EVENT TYPE TWO (TWELVE TRACKS)

The second event group brought together all instances where the calculated GS point coincided with the end of a key section within the composition. Of the twelve tracks included, six coincided with the end of the main breakdown, two coincided with the end of a break and four coincided with the end of an instrumental.

Event type two: end of key section					
Track	Duration	Calculated GS Point Time	Musical Event Point Type	Musical Event Point Start Time	Deviation %
2 Minutes	05:26	03:21	Breakdown End	03:21	+0.00%
EPA	04:52	03:00	Breakdown End	03:04	+1.37%
Waltz	04:10	02:34	Breakdown End	02:38	+1.60%
Airport	05:12	03:13	Breakdown End	03:18	+1.60%
Carta de Conducao	04:33	02:49	Breakdown End	02:56	+2.56%
Nargileh	04:58	03:04	Breakdown End	03:12	+2.68%
Slowhand Hussein	05:24	03:20	Break End	03:24	+1.23%
After	07:23	04:34	Break End	04:23	-2.48%
Around	03:41	02:17	Instrumental End	02:16	-0.45%
Basmati	05:27	03:22	Instrumental End	03:15	-2.14%
Debussy	04:27	02:45	Instrumental End	02:38	-2.62%
Barbeque	02:33	01:35	Instrumental End	01:30	-3.27%

FIGURE 10. EVENT TYPE TWO DATASET

Coincidence of the calculated GS point with the end of the main breakdown section was most prevalent, accounting for six of the twelve tracks, with the remaining instances marking other breaks and instrumental sections. While in the first event group the calculated GS point marked the beginning of the breakdown, the examples in this second event group occurred at the end of the breakdown, which would typically then transition into the final core section. It is argued that this is particularly significant, since the construction of EDM form indicates that the second half of the breakdown tends to ramp up towards the drop and the return of the core, representing the culmination or “highest intensity point” in the track (Solberg 2014: 70). To clarify using DJ Stanley’s EDM song map, this would correspond with the transition from section C to D.

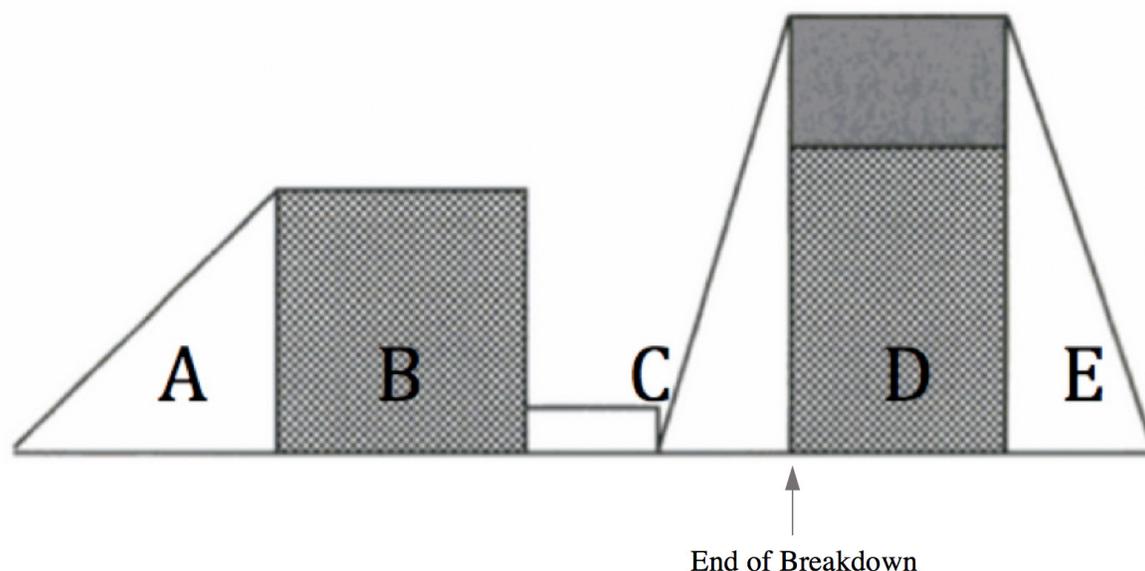


FIGURE 11. EVENT TYPE TWO MAPPED AGAINST EDM SONG MAP

In this sense, the Event Type Two breakdown examples evidence the calculated GS point coinciding with what could be argued as the pinnacle of the entire composition: the drop. Using *Airport* (2002) to illustrate, after a lead-in that introduces some of the melodic and rhythmic elements, the core is established and supported by full percussion. Subsequent to this, the track moves to a slightly less intense instrumental section which sees some layers, such as the prominent synth, removed, while other new instrumental parts are introduced to offer variation and contrast.

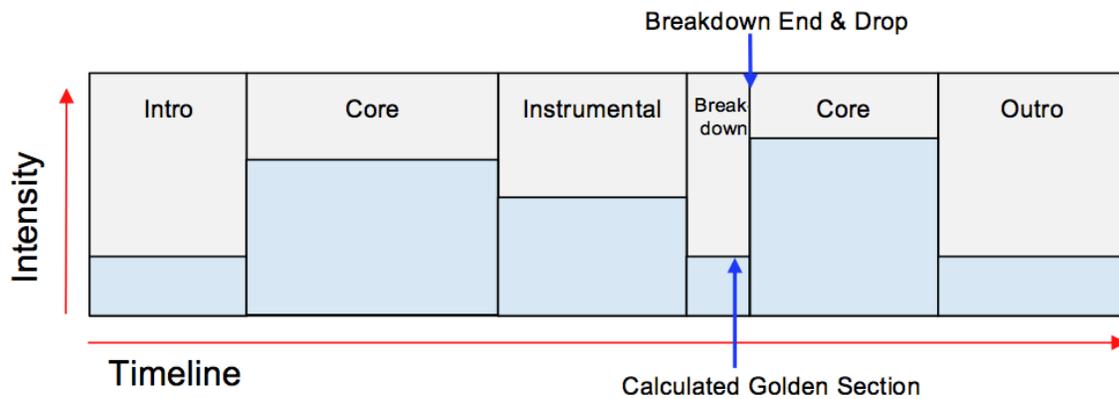


FIGURE 12. AIRPORT (2002) DUR. 5'12"

At the breakdown, the majority of the percussion drops away to leave just the main chord progression and melody playing against a minimal backdrop. The calculated GS point occurs three seconds (deviation 1.34 percent) before the end of the breakdown and the drop, at which point the core is re-established at its maximum intensity, supported by full percussion and other key instrument layers. Some unique parts are introduced after the drop, for example a trumpet line, which renders the final core section more prominent in the context of the whole composition. Finally, the track drops down to the outro and the end of the piece.

In addition to the six tracks with breakdown end events, two others—*Slowhand Hussein* (2000) and *After* (2000)—evidenced coincidence with less significant break sections which were either preceded and followed, respectively, by longer and more prominent breakdown events. As already explained, it was considered appropriate to distinguish between breakdown and break events.

Finally, there were four further instances where the calculated GS point coincided with the end of instrumental sections which also tended to then lead into the core at the end of the track: *Around* (2010), *Basmati* (2002), *Debussy* (2010) and *Barbeque* (2010). Interestingly, parallels can be drawn between these instrumental sections and the breakdown sections, since both seem to perform the unique and essential function of preparing the listener for a re-introduction of the core at the drop, as a final reprise of the track's main thematic material.

Regardless of the exact nature of each of these examples, they are united by the fact that the end of a clearly defined, discrete musical section, integral in establishing contrast within each piece, coincides closely with the calculated GS point. In many of these examples, this point of coincidence also represents the pinnacle of the composition. For more often than not, the end of the breakdown or instrumental marks the drop and/or a final reprise of the core at maximum dynamic intensity and extended duration.

EVENT TYPE THREE (TWELVE TRACKS)

The final event group brought together any remaining instances of golden section proportions aligned with clear musical events and sectional boundary points. This included examples where, in the absence of any coincidence at the 0.618 calculated GS point measured from the start of the track, the 0.618 calculated GS point was instead measured from the end of the track, or what has been termed here the *inverse* calculated GS point. Also included are instances in which the calculated GS point marked holistic structural proportions between verse/chorus groupings and ramp events, all of which are explained in more detail below. Out of the twelve tracks identified, seven marked key sections or structural proportions at the inverse calculated GS point, two marked other structural proportions in the compositions and three marked the start of a ramp event that built towards the drop.

Event type three: other musical event points					
Track	Duration	Calculated GS Point Time	Musical Event Point Type	Musical Event Point Start Time	Deviation %
Deep Disco	05:42	02:11 (inverse GS)	Instrumental Start	02:12	+0.29%
I Wish	04:39	01:47 (inverse GS)	Structural Proportion	01:48	+0.36%
Mad Man	05:06	01:57 (inverse GS)	Breakdown Start	01:52	-1.63%
Terrorist	05:10	01:58 (inverse GS)	Break / Instrumental Start	02:04	+1.94%
Drophere	04:27	1:42 (inverse GS)	Verse End, Chorus Start	01:48	+2.25%
Colores	03:27	01:19 (inverse GS)	Break Start	01:24	+2.42%
My Music	03:20	01:16 (inverse GS)	Structural Proportion	01:23	+3.5%
Take a Minute	03:31	02:10	Structural Proportion	02:08	-0.95%
Waiting	03:27	02:08	Structural Proportion	02:01	-3.38%
Stiff Jazz	05:50	03:36	Ramp Start	03:37	+0.29%
Spacewater	05:18	03:17	Ramp Start	03:16	-0.31%
Where Are We?	05:36	03:28	Ramp Start	03:32	+1.19%

FIGURE 13. EVENT TYPE THREE DATASET

In order to calculate the inverse golden section point, the same methodology was applied as was outlined earlier (taking a track's total duration and multiplying it by 0.618). However, instead of then measuring this calculated duration from the start of the composition, the

temporal measurement was taken from the end of the composition, which simply meant working with the same golden section proportions but in reverse order. What was found were further examples of coincidence with key sectional boundary points, including the start or end of breakdown and instrumental sections. For example, in *Deep Disco* (2010) after a short ambient introduction, the core is established with some slight variation in instrument layers until 2'12". Here, just one second after the inverse calculated GS point at 2'11", there is a pronounced change in direction as the track moves to an extended instrumental section that markedly contrasts the previous material. Subsequent to this, a short drum break at 3'52" signals a return to the core, which is then repeated *al fine*.

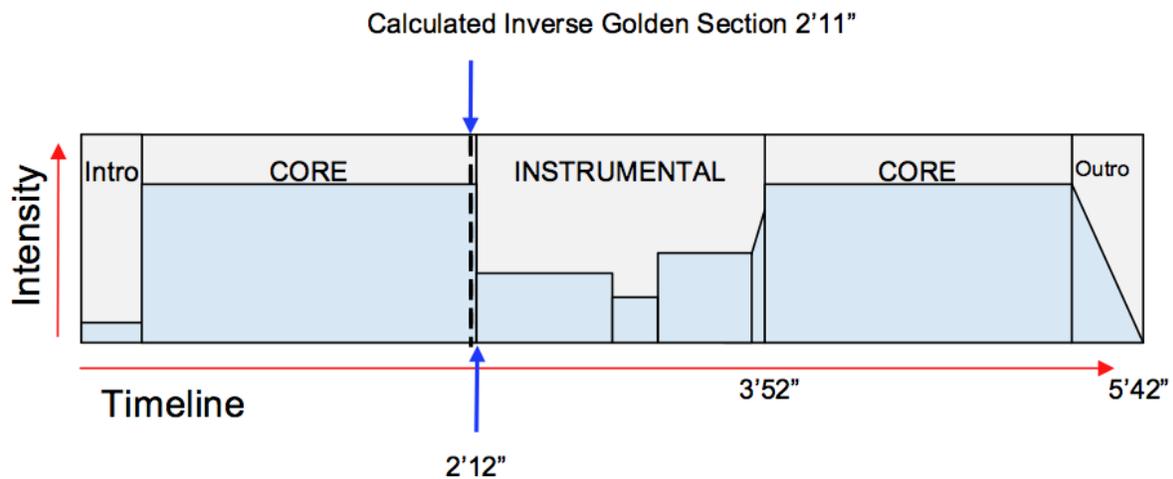
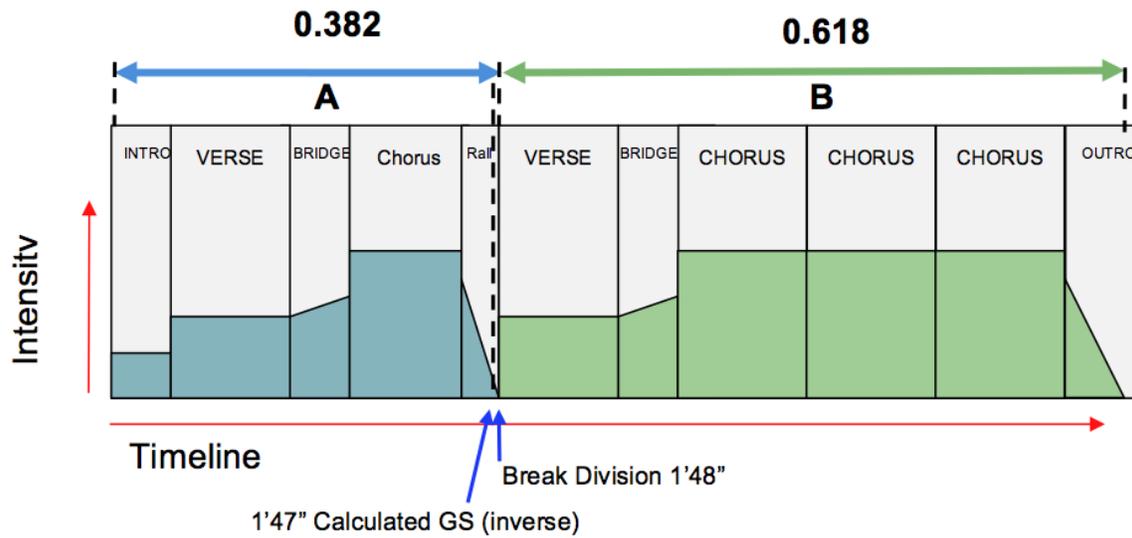


FIGURE 14. *DEEP DISCO* (2010) DUR. 5'42"

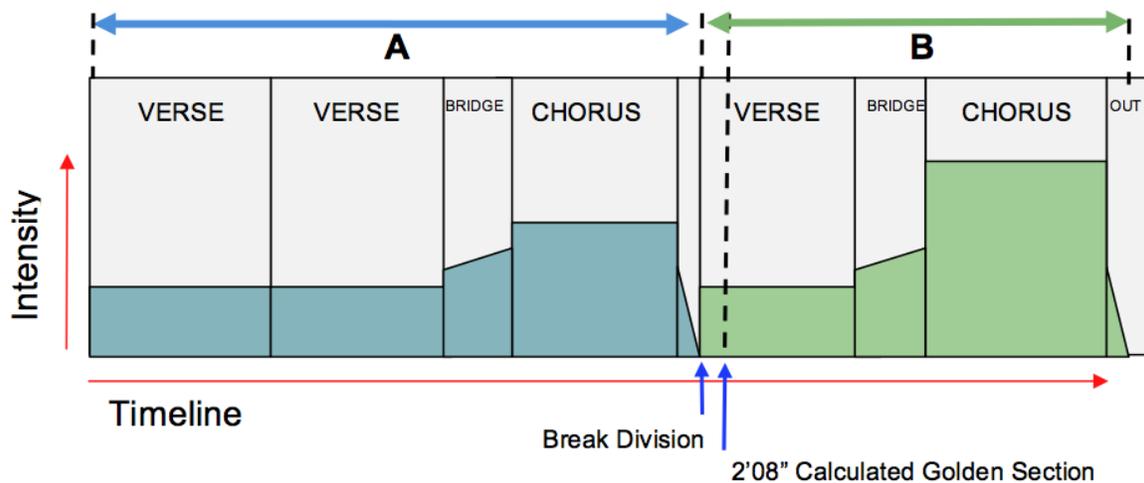
Here, one can clearly see a very close correlation (deviation +0.29 percent) between the inverse calculated GS point (2'11") and the start of the contrasting middle section (2'12"). Essentially, *Deep Disco*, along with a number of other tracks in this group, demonstrates similar attributes of GS coincidence to those discussed in the first two event groups, the only difference here being that coincidence is mapped against the inverse mathematical GS proportion.

Other instances of the inverse calculated GS point present compelling support of golden section alignment that becomes apparent when examining the structural proportions of the composition as a whole. For example, in *I Wish* (2005), the initial intro, verse, bridge and chorus are demarcated from the subsequent verse, triple chorus and outro by a short eight second section that slows to a brief pause. This is a unique moment in the track which seems to punctuate the whole composition by dividing it into two parts, A and B:

FIGURE 15. *I WISH* (2005) DUR. 4'39"

The ratio between former (A) and latter (B) parts portrays almost exact GS proportions of 0.382:0.618, with the inverse calculated GS point occurring at 1'47", just one second before the start of the new verse at 1'48" (0.36 percent deviation).

Similar proportionality can be found in the standard calculated GS point examples in this group, such as *Waiting* (2009), which can be subdivided into two. Part A consists of two verses and a chorus linked by a short bridge section. And part B is almost identical but only contains one verse. The calculated GS point occurs just after the end of the chorus in part A, at which point the track slows noticeably and attenuates in amplitude, adding an extra bar (two to three seconds) to the end of the chorus. This concludes part A and enables a transition to part B. Once again, this is a unique moment in the composition, and the perception is one of the music slowing to a momentary pause before the new verse is introduced.

FIGURE 16. *WAITING* (2009) DUR. 3'27"

Here, the calculated GS point could be interpreted to mark the division of the composition into former (A) and latter (B) parts which resemble golden section proportions, albeit approaching the limits of acceptable deviation at 3.38 percent. In a similar manner to *I Wish* (2005), this example is indicative of a more holistic representation of the calculated GS since it can be seen how the *entire* composition (A:B, or A+B:A) corresponds with golden section proportions (0.618:0.382 and 1:0.618 respectively).

Finally in this group, three instances were identified in which the calculated GS point marked the onset of musical and dynamic changes within the breakdown that indicated a build or ramp towards the drop: *Stiff Jazz* (2002), *Spacewater* (2000) and *Where Are We?* (2000).

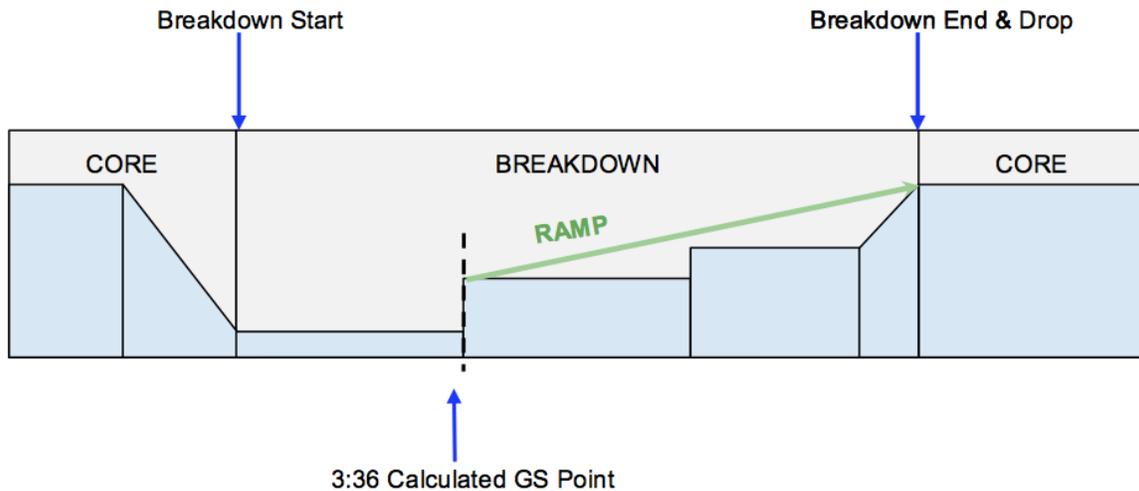


FIGURE 17. *STIFF JAZZ* (2002) DUR. 5'50"

In these cases, each track transitions from core to breakdown and in doing so moves from a higher to lower intensity. Fewer instrument layers result in an ambient, open feel. Looking at *Stiff Jazz* (2002) as an example, the breakdown starts to build at 3'37", just one second after the calculated GS point (deviation 0.29 percent). The onset of the ramp is marked by the introduction of new instrument layers which provide a change of direction and a renewed sense of momentum, and the section continues to build in intensity as the drop approaches and all instrument parts are re-introduced for the core at 4'15". To reiterate an earlier point, given the significance of the drop as the pinnacle of the whole track and the moment at which the final reprise of the core occurs at maximum dynamic intensity, these ramp events seemed particularly noteworthy.

SUMMARY

From the sixty-six tracks subject to analysis, forty-five tracks supported alignment of the calculated GS point with significant musical events to within 3.5 percent deviation. This corresponds to a striking 68 percent of dZihan & Kamien's tracks—just under five and a half hours of music—which evidence golden section proportions.

Of these tracks, deviation ranged from 0.0 to 3.5 percent with a mean average of just 1.58 percent, signifying a close alignment between the mathematically calculated GS point and the occurrence of key musical events. As a reminder, this deviation figure is an indicator of how closely the calculated GS points occurred in relation to the coincident musical event points, and thus a smaller deviation percentage value denotes a closer representation of golden section proportions within the music. These figures are broken down further in the schematic below, enabling comparison between the different Event type groups and against the overall aggregated figures.

Group	Lower Range	Median	Mean	Upper Range
Event Type 1	0.38	1.12	1.46	3.18
Event Type 2	0.00	1.87	1.83	3.27
Event Type 3	0.29	1.41	1.54	3.50
All Groups 1-3	0.00	1.39	1.58	3.50

FIGURE 18. DEVIATION PERCENTAGE OVERVIEW

Visualising this data graphically enables a better appreciation of its significance; the box plot below presents the average median and mean deviation amounts with the minimum and maximum deviation values at the lower and upper range boundaries and the interquartile range. This represents the midspread or central grouping of deviation values:

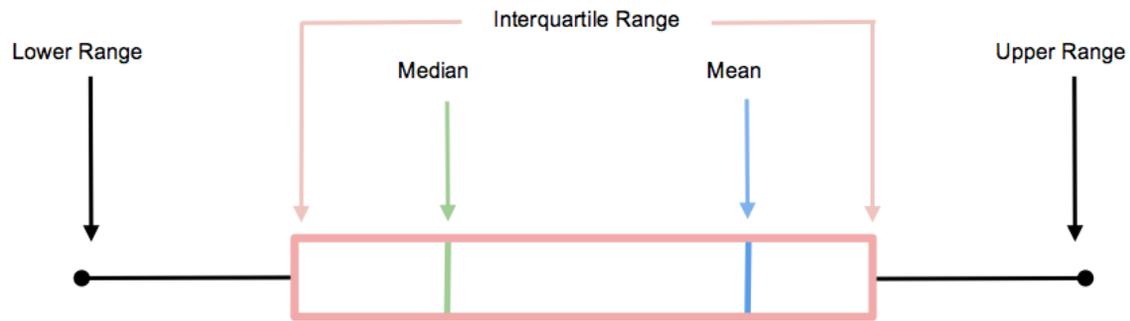


FIGURE 19. BOX PLOT KEY

Thus, the box plot for each Event group illustrates the deviation measurements for all tracks included within that group. Each deviation measurement represents the time difference between the calculated GS point and the musical event point identified for each track. The further one moves to the left side of the graph, the lower the deviation, indicating a closer coincidence between calculated GS point and musical event point.

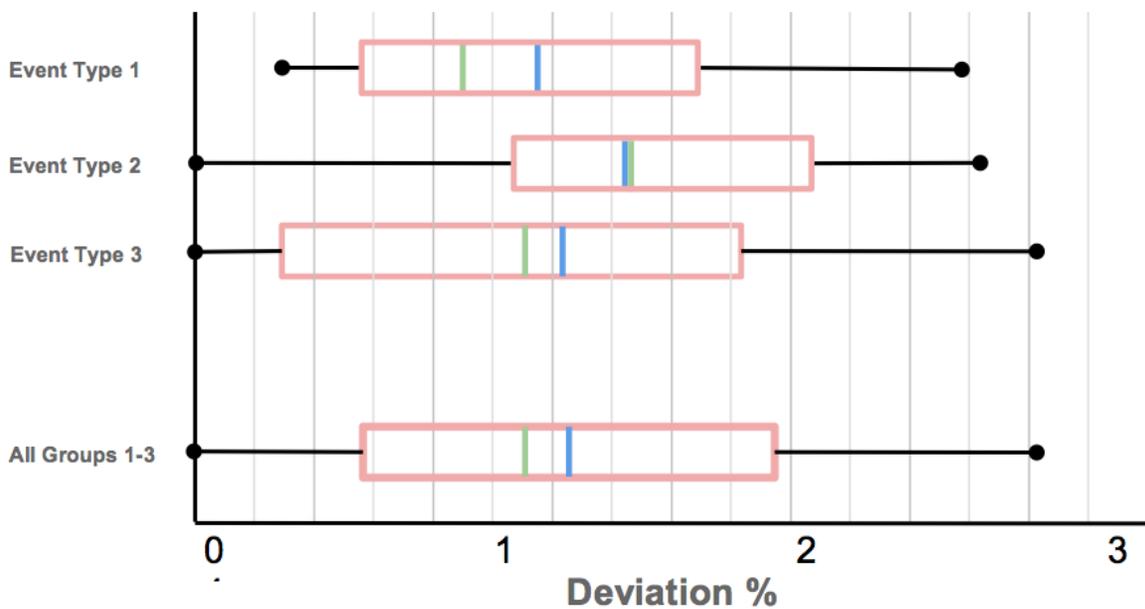


FIGURE 20. DEVIATION PERCENTAGE OVERVIEW BOX PLOTS

Although originally setting a deviation threshold of 3.5 percent, the data actually indicate that the majority of tracks were well below this limit, as evidenced by the interquartile range for All Groups spanning from 0.7 percent to 2.42 percent. Therefore, the majority of the data would remain credible even within more stringent margins, such as the 2 percent “reasonable margin” described by Adams (1996: 244).

DISCUSSION

The journey which began with an early intuitive hunch that one or two tracks from the creative output of dZihan & Kamien might perhaps reflect golden section proportionality led to an in-depth analysis of over sixty of their songs. Experimental findings indicate that some sixty-eight percent of their tracks align to, on average, just under 1.6 percent overall deviation of the identified key structural events from the mathematically calculated golden section.

Acquiring this data meant implementing a different methodological procedure from any previously described in the literature. EDM-based music is not predicated on a musical score, but upon the use of DAW technologies. So it made sense to abandon score-based counting approaches, which have dominated golden section music analyses, and replace them by counting elapsed time. As pointed out earlier in this paper, there have been some not insignificant concerns by respected analysts themselves around the reliability of the counting bars methodology, in the main due to the inconsistent tempi across analysed works. However, in this study, the overwhelming majority of pieces under scrutiny employ a stable, consistent tempo. Additionally, there are no comparable issues regarding variations in performance interpretation from the composer's intended tempi, since each track/song exists as a finished recorded artefact. In effect, the creative acts of musical composition and production are one and the same. Counting in minutes and seconds not only releases the methodology from these issues but focusses the demarcation of key musical event points away from discerning them on a printed page to an aural apprehension of how such event points manifest themselves in experienced time.

As stated earlier, the bulk of studies on the golden section in the arts sit in the visual domain, and in this context the perception of proportional relationships is both holistic and simultaneous. For example, the proportional relationships lying within the various dimensions of a mediaeval cathedral, or the interrelationships between various components within a painting, can be apprehended in one moment. In the case of music this is not possible since it is time-contingent. Reybrouk suggests that, "since music is a temporal art [it] is characterized by the *consumption* of time. In distinction to, for example, a geometric figure which is perceived at a glance, it relies on the successive presentation of its component parts" (Reybrouk 2005: 12). And as Ray Howat points out, "if a painting or building is clumsily proportioned, a sensitive observer can see the fact in an instant; in music, though, we have to hear the piece through to make the equivalent evaluation" (1983: 1). In other words, when listening to music it could well be that the golden section is perceived retrospectively, after the event.¹⁵ Allan Atlas semi-humorously notes that this perception is "a far more complicated affair than that of spatial proportions, which are nice enough to stand still" (2003: 282). And as Boykan has rather acerbically pointed out, "you can easily compare lengths in the visual world, but it is rather a stretch to ask us to keep track of a ratio in a situation of gradual unfolding" (2004: 25-6).

These are however, issues that relate more to the psychology of musical perception, which sits outside the scope of the current paper. When looking at how proportionality might function within the actual creative *act* of composition rather than its later perception, the matters of holistic visualisation described above may, particularly in the setting of digital compositional tools, be relevant. Macchiusi describes such a setting: “the DAW’s particular visualisation of a composition as a compound graphical object, temporally delineated and stretched across a timeline, highlights a modular form of arrangement that centers a spatial analysis of music” (2017: 9). This spatial aspect, he continues, “is emblazoned across the screens of countless (music) producers, making up an integral part of their process” (Macchiusi 2017: 122). And within the spectrum of visual environments in a DAW, it is the so-called “arrange window” which allows the musician to comprehend what Macchiusi describes as the “synoptic outline” of the entire composition.¹⁶ This leads to the possibility that in such a creative digital workspace, the composer/arranger may be influenced—consciously or otherwise—by the visual representation of the emerging composition. Macchiusi goes on to state that, “Creating visual clarity forces many producers to constantly think analytically, *visually defining the form and function of various sections of their arrangement* while still in the midst of the compositional process” (2017: 142; our emphasis).

In email correspondence with dZihan & Kamien this sense of synoptic visualisation was echoed when Vlado Dzihan said that, “as a composer/producer you develop more of a bird’s-eye when you work on a piece, and that gives you a better overview regarding the flow between energy, pauses, dynamics, silence.”¹⁷ This “birds-eye overview” might be used by any composer engaged in the creative act of composing, but it may well be reinforced even further by contemporary composers through their use of screen-based tools such as the DAW. The authors of this paper suggest that these digital tools might naturally engage a visual, holistic appreciation of possible golden section proportions upon the computer screen which might then in turn be translated into temporal music and sound events. This has been echoed by Marrington in his study of DAW-based musical composition.

...the entire composition can appear as a single entity on the screen. This presents an interesting deconstruction of the established notion of the composition as a design made apparent through unfolding in time and further emphasizes the composition as object in visual space (Marrington 2010: 5).

Exploring this possibility inevitably then leads to the consideration of matters of compositional intentionality. In some of the literature, issues of conscious intention are discussed: to what extent is the musician aware of the golden section and how consciously do they incorporate such proportionality into their work?¹⁸ From our written communication with Vlado Dzihan it was very clear that he had no deliberate intention to incorporate the golden section into his music.

Vlado Dzihan: I'm familiar with these [the golden section and proportionality in music] although I do not have a specific knowledge about it.... I also believe that a formula or intention to use these principles on purpose to make music would turn out rather uninspiring.¹⁹

And when asked how the duo establish an effective balance between sections when structuring their music, Dzihan says it is “rather an instinct than a formula”. Structuring a piece of music for him is...

Dzihan: ...similar to speech—you also do not talk in one stream, you take a breath, you make a pause, you might look for a right expression, you get louder or softer, etc. So it is the same with music—for instance, the tension, the focus might be given by the pauses and the silence.

Clearly, the act of composition described here is heavily reliant upon creative intuition and feel rather than the intentional use of any formal compositional procedures over and above any general alignment with EDM generic structures. If not intentional, the question then arises as to why some sixty-eight percent of the creative output of dZihan & Kamien, sustained over a period of twenty years, reflects golden section proportionality to such a close degree?

CONCLUSION

From the findings outlined, the authors of this paper are led to enquire whether the serious exploration of the golden section in music should remain largely confined to the domain of classical music. And from this case study of just one aspect/sub-genre of popular music it seems not. Using a time-based rather than score-based methodology as a foundation or jumping-off point, it may be possible to explore a further range of popular music genres in terms of golden section proportionality and any associated impact upon the creative processes involved in the composition of music. To what extent the digital audio workstation—with its visual representational overview of an unfolding composition—might influence these processes is potentially another line of enquiry worthy of future study, which would be particularly relevant to contemporary music composition, given the prevalent use of DAWs in such music.

ACKNOWLEDGMENTS

We thank Vlado Dzihan for their correspondence during the study. This offered valuable insight into the creative approach of the duo, which was particularly useful when considering the findings of our analysis.

NOTES

- 1 See for example Oldershaw (1982), Green (1995), Zeng and Wang (2009), Chen et al. (2011) and Luttge and Souza (2019).
- 2 A most recent and unexpected occurrence is to be found in the official press conference video for the Fiat 500, <https://www.youtube.com/watch?v=pVBAzeu-HZg> (at 9'37").
- 3 Zeising's work has been contested by Tatlow in her comprehensive historico-critical overview (see Tatlow 2006: 69-85, where she refers to the practice of "golden numberism" beginning in the 1830s). Tatlow's critique, however, is primarily concerned with matters of compositional intentionality.
- 4 Lendvai has undertaken extensive analyses of the compositions of Bartók (see Lendvai 1966a; Lendvai 1966b), while Howat's (1983) comprehensive book explores the golden section in the music of Debussy.
- 5 Examples from the fourteenth and fifteenth centuries include Machaut (Powell 1979), Dunstable (Trowell 1979), Dufay (Sandresky 1981), through Mozart (Perry Camp 1968), to the 20th century with composers such as Satie (Adams 1996), Shostakovich (Rofe 2016), Stockhausen (Maconie 2005) and Ligeti (Luchese 2001). Jonathan Kramer (1988: 303-4) offers a wider range of composers.
- 6 With reference to the musique concrète tradition, Lewis (1998) discusses Dhomont's Novars, the structure of which is based on multiple golden sections, while Zattra (2007) undertakes a textual criticism approach in her analysis of John Chowning's electroacoustic work *Stria* and its associated linkages with the golden section.
- 7 Exploring possibilities of golden section in instrumental music avoids any potential constraints of popular music song structures which are based on rational numbers (e.g. 4, 8, 16).
- 8 There is some slight drift in the tempo in some tracks such as *Weltempfänger* (2010).
- 9 Publications that have referenced this overview of EDM form include Snoman (2013), (Solberg 2014), Eigenfeldt and Pasquier (2015) and López-Serrano et al. (2016).
- 10 We are mainly applying here what Lendvai refers to as the positive (long musical section followed by shorter section at 0.618) rather than the negative (short musical section followed by longer section at 0.382). We are not applying any complex aspect of the nesting of GS points such as in the analyses by Howat.
- 11 Taking Adams' concerns into account with respect to *Ocean Air*, for example, the two thirds/one third issue would have placed a calculated point of two thirds of the total duration of 5'20" to occur at 3' 33", some distance from the hypothetical GS point of 3'18".
- 12 For example, in *Waiting* (2009, dur 3'27"), this division occurs at 2'01", splitting the song into former (verse-verse-chorus) and latter (verse-chorus) parts that are representative of GS proportionality, 0.618:0.382.
- 13 The inverse calculated GS point was arrived at by calculating the normal GS point using the previously outlined methodology, but then measuring from the end of the track, as opposed to the start. Essentially, this inverts the order of the larger and smaller GS proportions.
- 14 To clarify, in EDM form, the breakdown constitutes the longest, most dramatic break from the core, and thus any occurrence of a break section in this present study which did not closely meet the EDM definition or was eclipsed by another more prominent instance in the track, was classified not as a breakdown but as a break.

- 15 See also Phillips (2019).
- 16 The arrange window is the main workspace within a DAW where regions, containing different musical sequences, are repeated, layered and sequenced across a timeline, thereby creating the desired musical arrangement. These regions are visually represented on the screen as blocks of different colours, which the user is able to manipulate using the mouse.
- 17 Email correspondence with Vlado dZihan, 15th June 2020.
- 18 Issues of conscious intention are discussed primarily with respect to the work of Debussy and Bartók.
- 19 Ibid., dZihan (2020).

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