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MELODY AND WORD ACCENT RELATIONSHIPS IN ANCIENT GREEK MUSICAL DOCUMENTS: THE PITCH HEIGHT RULE

Abstract: It has long been known from the extant ancient Greek musical documents that some composers correlated melodic contour with word accents. Up to now, the evidence of this compositional technique has been judged impressionistically. In this article a statistical method of interpretation through computer simulation is set forth and applied to the musical texts, focusing on the convention of correlating a word's accent with the highest pitch level in the melody for that word: the Pitch Height Rule. The results provide a sounder basis for judging evidence for the operation of this convention in specific pieces and a sharper delineation of its use in the history of ancient Greek music. The 'rule' was used by at least some composers from the late second century BC through the second century AD, but there is no certainty that it was used before or after this period. In some cases where previous scholars have discovered the rule's operation, statistical analysis casts doubt. Of special interest is the showing that one piece long judged as offering no evidence of the use of the rule probably displays an inversion or parody of the rule for rhetorical-musical effect.

It has long been recognized that in some pieces of ancient Greek music the melody reflects the influence of the verbal accents in various ways.[1] The 'rules' of accent/melody relations are abstractions from observed tendencies in the musical documents. They are *conventions of composition*. The Delphic paeans display the most consistent and complex adherence to such conventions, which can be summarized as follows:[2]

1. The accent-bearing syllable of a multisyllabic word (two syllables or more) carries a note as high or higher than notes for other syllables in that word. In cases of melisma, the highest note of the melism is what counts for adherence to the rule.

2. The melody often falls after an acute accent; in polysyllabic words (three syllables or more), the melody often rises to and then falls from the acute.

3. The circumflex accent is usually set to a falling figure.

4. After a grave accent, except in cases of a grammatical pause, the melody does not fall again until after the next accent. Successive grave-accented syllables tend to be set to the same note.

With the recent publication of a second, expanded edition of Egert Pöhlmann's collection of ancient Greek musical documents,[3] the old subject of the relation between melody and word-accent in ancient Greek music deserves to be revisited. In fact, a thorough analysis has not been undertaken in fifty years. In the meantime more documents have been published, some of them substantial. Warren Anderson's call in 1983 for a painstaking analysis of the evidence in all the musical fragments has remained unfulfilled.[4]

[1] A correlation of melody and word-accent was first observed by Otto Crusius in the Seikilos inscription. See O. Crusius, 'Zu neuentdeckten antiken Musikresten: I. Nachträgliches über die Seikilosinschrift; II. Fragment einer Partitur des euripideischen Orestes', *Philologus* 52 (1893) 173.

[2] The following formulation of the rules is a summary based on the observations of R.P. Winnington-Ingram, 'Appendix II: Melody and word-accent', in S. Eitrem, L. Admundsen and R.P. Winnington-Ingram, 'Fragments of unknown Greek tragic texts', *SO* 31 (1955) 1-87 (Appendix II: 64-73). See also M.L. West, *Ancient Greek Music* (Oxford 1992) 199.

[3] First edition: E. Pöhlmann (ed.), *Denkmäler altgriechischer Musik. Sammlung, Übertragung und Erläuterung aller Fragmente und Fälschungen* (Nürnberg 1970); revised edition: E. Pöhlmann and M.L.West (eds), *Documents of Ancient Greek Music: The Extant Melodies and Fragments Edited and Transcribed with Commentary* (Oxford 2001) (henceforth: *DAGM*).

[4] W.D. Anderson, 'Word-accent and melody relationships in ancient Greek musical texts', *Journal of Music Theory* 17 (1983) 198.

The present study is not a comprehensive treatment of all the melody/accent relations in ancient Greek music but offers a thorough examination of one of the most widespread tendencies: that the accented syllable carries a note as high as or higher than any notes for other syllables of that word. For convenience, we term this the Pitch Height (PH) rule.

PROBABILITIES OF CHANCE PH ACCORD

Almost every ancient Greek musical document shows some degree of 'PH accord', if we use this expression in a neutral sense to mean consonance with what the rule requires, whether that agreement is by chance or design. Judging whether a given pattern of accord is by design cannot be a matter of simply noting whether breaches are 'many' or 'few', since these terms are relative. Only percentages are meaningful. Interpreting percentages requires some prior knowledge about what chance would produce. What percentage of PH accord would occur without any conscious or unconscious design on the part of the composer? For example, in the case of the Christian hymn (*P.Oxy.* 1786), opinion is divided about whether the evidence suggests design or mere chance. Winnington-Ingram counts 13 of 20 instances of PH accord and sees some tendency for the circumflex accent to be set to a falling melodic pattern. In view of this evidence, he remarks that 'it is hard to deny all influence of the accent, which is, however, sacrificed fairly freely to the melodic formula'.[5] Rudolf Wagner also judges that one can find an influence of the word accent on the melody.[6] But Pöhlmann and Théodore Reinach find no evidence that the composer paid attention to the PH rule.[7]

In judging whether PH accord is by chance or design, we have to consider a number of variables. One is the number of possible notes. For example, in a song using a scale of only two notes (say, *f* and *g*), the chance PH accord possibilities for a two-syllable oxytone are as follows: *f f* (accord); *g g* (accord); *f g* (accord); *g f* (non-accord). This makes for a 75% likelihood of accidental accord. A song with a two-note scale and, say, twenty multisyllabic words, all containing two syllables, would have a good chance of showing 75% accord (15 of 20) apart from any effort by the composer to follow the PH rule. But not every song of this type would show 75% accord. Some would show less, some more. PH accord for a large group of such songs would distribute in a bell curve whose peak would be the possibility (75% accord) that obtains most frequently, perhaps a third or so of the time. If our song used three notes (say, *e*, *f*, *g*) the possibilities of chance accord for a two-syllable oxytone would go down: *f f* (accord); *g g* (accord); *f g* (accord); *g f* (non-accord), *e e* (accord), *e f* (accord), *e g* (accord), *f e* (non-accord), *g e* (non-accord). That is a 66.66% possibility of chance accord for any word of this type, instances of which would also distribute in a bell curve formation in any given song.

The preceding assumes that the number of possible notes is the number of notes in the scale for the piece. But figuring possible notes is actually more complicated. Greek melodies tend not to make many large intervalic leaps.[8] At any moment of composition, the compass of notes from which the composer is likely to choose is usually less than the scale represented by the notes used in the piece. For example, the first song of *P.Yale CtYBR* inv. 4510 uses a scale of seventeen notes (just over two octaves), but melodic intervals tend to stay within a range of five

[5] Winnington-Ingram (n.2) 71.

[6] R. Wagner, 'Der Oxyrhynchos-Notenpapyrus', *Philologus* 79 (1924) 205. So also J.U. Powell and E.A. Barber (eds), *New Chapters in the History of Greek Literature*, second series (Oxford 1929) 165; H. Abert, 'Ein neu entdeckter früchristlicher Hymnus mit antiken Musiknoten', *ZfMW* 4 (1921/22) 528.

[7] Pöhlmann (n.3)109; Th. Reinach, 'Un ancêtre de la musique d'Église', *RMus* 3 (1922) 19 n.2.

[8] West found that of 2200 two-note sequences, 22% show a repetition, 47% show a move to the next nearest note (up or down), 19% show a move to the next nearest degree, and 12% show a move to some more remote degree. See West (n.2) 191-2.

notes and the average melodic movement is only 1.37.[9] Examination of the scores reveals that the average range of notes per multisyllabic word is typically about a four-note compass. This tendency to use a narrow compass of notes increases the likelihood for chance PH accord. The reason is simply the mathematical logic illustrated in the examples above with two-note and three-note scales. Moreover, since the PH rule states that accord obtains if the note carried by the accented syllable is *as high or higher* than the note for any other syllable, the tendency to repeat notes influences chance accord. Everything else being equal, a song that repeats notes 45% of the time will show more instances of accidental accord than a song that repeats notes 15% of the time. Successively repeated notes are such a powerful influence on chance PH accord that we find it useful to consider repetition as an independent variable alongside intervalic movement (the two together making up melodic movement).

One other consideration is that composers tend not only to operate within relatively narrow note ranges at any given point in their compositions but also to use some specific notes with greater frequency than others. The 'tonic' is such a note (the tonic being the note around which the melody tends to revolve through placement and recurrence). Depending on the piece, other notes may also be slightly preferred. It is difficult to know exactly what effect a more frequent use of a certain note or notes may have on chance accord. In our simulation methods, described below (see under 'Method II' below) we seek to take account of any effect.

A third variable is the number of syllables in a word. Our hypothetical two-syllable word (see above) had a 75% probability of showing PH accord in a piece using a two-note scale. The probability of a three-syllable word in the same song showing accord is only 62.5%. Given the power of repeated notes to produce chance accords, a robust repeated-note percentage and a high proportion of two-syllable words will work in tandem to increase the likelihood of chance accord.

From the preceding we can draw out three principles of chance accord: (1) as the proportion of polysyllabic words (and their number of syllables) goes up in comparison to two-syllable words, the likelihood of chance accord goes down; (2) as the note compass (range of intervalic movement) goes up, the likelihood of chance accord goes down; (3) as the repeated-note frequency goes up, the likelihood of chance accord goes up.

COMPUTER-GENERATED SIMULATIONS OF CHANCE PH ACCORD

In previous interpretations of melody/accent accord, judgements have been impressionistic. Sometimes impressions are reliable, but not always. For example, there can be no doubt that the PH accord patterns in the Delphic paeans are products of compositional design. The Paean of Athenaios shows PH accord for 77 of 79 analysable words (97%);[10] the Paean of Limenios shows PH accord for 100 of 101 analysable words (99%).[11] But what about pieces showing degrees of accord well over 50% but substantially under 100%? Or pieces where the percentage of accord is very high but the number of analysable instances is low, e.g. four of four? Impressions in such cases can be misleading.

We propose computer simulation and analysis of melody/accent relations as a statistical method for discovering what chance would produce. In this approach we use the words of a specific piece of ancient Greek music and information about the melody of that piece to generate thousands of random matchings of word sets with melody strings. In this way we can determine the random frequency of the actual PH accord for a given piece in simulations that mimic the specific variables (word types, intervalic movements and repeated notes) of that piece.

[9] The figure '1.37' is obviously not an actual interval but a fraction resultant from averaging. We obtained this average by using only readings about which there is confidence. Keeping in view what matters for PH accord, we considered melodic movement as 'syllable to syllable' and counted only highest notes in cases of melisma.

[10] Clashes in φερόπλοιο (l. 10) and θνατοῖς (l. 20).

[11] Clash in δικόρυφον (l. 2).

For example, if a piece of music shows 10 of 15 PH accord, we can discover how often that result occurs by chance in, say, 100,000 random simulations using the words of that piece and data about its melody. More importantly, we can also determine the chance frequency of ten *or more* instances of accidental accord. In statistical parlance, the cumulative percentage of frequencies equal to or greater than a given result is called the *p*-value. Thus, if *10 or more* out of 15 occurs 30% of the time, the *p*-value for 10 is .30 or 30%.

P-values are what count in statistical analysis for judging whether a pattern is by design. They are used as a way of summarizing the evidence for an *alternative* hypothesis (pattern produced by design) against a *null* hypothesis (pattern produced by chance). In our study this applies as follows. Our null hypothesis is that the composer has paid no attention to the PH rule; the alternative hypothesis is that the composer has used the rule to shape the melody (whether consciously or unconsciously[12]).[13] The common standard for rejecting the null hypothesis is $p < .05$. This is not a mathematically bright line but only a rule of thumb. It is also a conservative one, marking off a statistical space beyond reasonable doubt.[14] Using this norm, one can consider PH accord frequencies associated with *p*-values under 5% as evidence of compositional design. But higher *p*-values are not disqualified as evidence of design. *P*-values are simply a measure (on a continuum) of evidence against the null hypothesis. Hence, instead of using $< .05$ as a fixed threshold, statisticians commonly simply report *p*-values and let readers make their own judgements. We encourage readers to do that with the results presented below.

It is important to stress that the *p*-value does not provide evidence *for* the null hypothesis. Hence, a *p*-value of 50% is not stronger evidence favouring the null hypothesis than a *p*-value of 10%. The *p*-value is only a summary of the evidence for the *alternative* hypothesis. Therefore, *p*-values bear on the null hypothesis only neutrally or negatively, permitting only one of two inferences: that there is enough evidence to reject the null hypothesis (and embrace the alternative) *or* that there is not enough evidence to reject the null hypothesis.

METHODS FOR COMPUTER SIMULATIONS

For the results of the simulations to be reliable, the melodies generated by computer must resemble as closely as possible the melody of the piece itself. But there is more than one reasonable way to produce such melodies. Therefore, we developed three methods of melody construction. Each method calls for a set of composition rules tailored to the piece of music in question. They instruct the computer to generate melodies based on the scale used by that piece and the nature of the song's melodic movements. The computer randomly matches the multisyllabic word types found in the piece (coded simply as 'three-syllable word with accent on second syllable', etc.) to the melody strings.[15]

We applied all three methods to each song tested. In some cases we ran simulations using two different word sets for a piece: a *confident* reading and an *expanded* reading. The confident reading is a set of words about which judgements concerning PH accord are certain or nearly

[12] We think that composers did this shaping consciously because in certain respects the melody/accent rules differ from the significance of accents in speech (e.g. the voice falls on the grave in speech but is treated as high by the PH rule). The melody/accent relations may be a stylizing compositional technique – perhaps also archaizing if the tonal accent was being replaced in the Roman period by a dynamic accent. But it is also possible that the tonal accent persisted for a time as the dynamic accent developed. See West (n.2) 200.

[13] In the case of one piece, we use a different alternative hypothesis in order to test whether there is evidence that the composer went deliberately *against* the PH rule. See the analysis of *P.Berlin* 6870 (ll. 16-19) below.

[14] Where stakes are high (e.g. drug trials), $p < .01$ is used.

[15] Sometimes accent placement has an effect on chance accord, but usually it makes no difference.

so.[16] The expanded reading includes additional words based on the reasonable readings and supplements in *DAGM*. We might have used only confident readings, but it seemed important to give some sense of how the counts look when one uses both a strict and a more relaxed (but still judicious) standard of inclusion. As it happens, we found that the simulations results for confident and expanded readings in most cases differed only modestly and hence were mutually confirming.

The following is a description of the three methods.

Method I

> Compositional rule 1: Use the following notes: [the scale used by the piece as implied by the notes found in the piece].
>
> Compositional rule 2: Start with [opening note or interval where known, or a random starting note]; choose ending note at random.

We used fixed opening intervals, where they are known, because an opening rise at the beginning of a piece or section appears to be a common tendency among ancient Greek composers.[17] How a piece opens affects where it goes according to the composition rules, which accounts for the small differences we noted when we specified the starting note or left it random in preliminary tests. We used fixed opening two-note sequences for the Seikilos epitaph, Invocation of the Muse, *P.Berlin* 6870 (ll. 16-19), *P.Ashm.* inv. 89B/31, 33 *fr.* 1, and *P.Oxy.* 1786 (simulating the rise at σιγάτω).

> Compositional rule 3: Construct the sequence of notes according to the following probabilities for the total simulation: [types of melodic movement expressed in percentages reflecting those of the piece].

Melodic movements are various kinds of intervalic movement and repetition. Probabilities are based on counts of these different kinds of movement within the piece, using only those analysable instances where we can be confident about the readings. Since PH accord concerns only the highest pitch of each syllable, we used an abstracted melody pattern from the highest note of a syllable to the highest note of the next syllable. Here is an example of the counts and corresponding percentages taken from the composition rules for the Seikilos epitaph:

Same note: 5 (18%)
Up 1: 5 (18%)
Up 2: 4 (14%)
Up 4: 1 (4%)
Down 1: 9 (32%)
Down 2: 4 (14%)

Notice that repeated notes and stepwise (conjunct) movement account for 68% of the melodic movements from syllable to syllable in this song.

[16] Confident readings include words with no uncertain letters and notation, words where uncertainty about letters or notation does not affect judgements about PH accord, words where other possible readings (in the *DAGM* apparatus) show the same result for accord, and a very few cases, mentioned explicitly below where they arise, in which other factors warrant confidence about a PH accord judgement even with missing or uncertain notes.

[17] See West (n.2) 192-3.

> Compositional rule 4: Do not repeat any note more than [the maximum repeats in a row found in the piece].

Rule 4 governs how many repeats can occur overall in the simulations, but we wanted to avoid extremes, e.g. melodies made up mostly of repeated notes. Hence, we limited the number of repeats that could occur *in a row* to the maximum number of consecutive repeats in the piece.

> Compositional rule 5: At the lowest note, go up or repeat in accord with Rules 3 and 4; at the highest note, go down or repeat in accord with Rules 3 and 4.

This rule simply instructs the computer to do the obvious. But it needs to be told; otherwise it will get stuck.

> Compositional rule 6: Randomly match the words to strings of melody 100,000 times.

Trial simulations showed that it makes no difference in what order the words are matched to the randomly generated melody strings. Each random word/melody relation is its own universe, so to speak.

Method II

> Compositional rule 1: Use the following tone row for each simulated matching of words and melody: [specify a tone row abstracted from the piece].

The approach of method II is to use the notes of the piece in the order in which they appear in the melody. In defining the tone row, we begin with the melody abstract used in method I, which consists of the highest notes for each syllable. We do not distinguish here between certain note readings and those about which there is some doubt but use all the note readings given in the *DAGM* transcriptions. We treat gaps (caused by illegibility or missing areas of the document) by simply closing them. Sometimes, however, we add a linking note to break up large intervals across a gap, so that in closing gaps we do not create too many additional large intervals out of character with the nature of the piece.

Linking across gaps produces intervals that substitute for the notes that once filled those gaps. But a collateral effect can be a reduction in the overall percentage of repeated notes. Repeats are the most frequent single melodic movement in Greek music and a powerful factor in producing chance accord. The production of intervals through crossing gaps often does not result in as many repeats, proportionately, as Greek composers tended to use. To compensate for this we have added some repeats to the tone rows where this was necessary to make the percentage of repeated notes equal to or within a few points of that used in method I for that piece.

One of the values of using the tone row is that it addresses the question, raised above, of a possible effect on chance PH accord from the tendency of composers to use a certain specific note or notes more frequently than others. By using a tone row made up of the composer's own note choices, method II takes this effect into account.

> Compositional rule 2: Randomly match the words to the tone row 100,000 times.

Method III

Method III applies the frequencies of kinds of melodic movement to each discrete melody/word-set combination rather than to the simulations as a whole (method I). This means that the computer creates random melody strings by applying the *counts* for each type of melodic movement (counts derived from the actual piece) to each melody string. Thus, for example, each string might have three movements up a third and two down a second, and so forth. Since the order in which these movements occur varies randomly, the melodies differ, but they share in common the same sets of movements. By contrast, in method I, the kinds of melodic movement, formulated as percentages, are applied to the set of simulations as a whole, not to each individual melody string. Consequently, with method I, individual melodic strings can differ in the kinds of movements they display. But for the 100,000 simulations as a whole, the percentage of each type of movement matches the percentage derived from the actual song.

In method III, using the actual *counts* for types of melodic movement created a minor problem. In cases where a piece is fragmentary, the counts usually show an imbalance between upward movements and downward movements, which often causes the computer to run out of notes in one direction or the other as it seeks to fulfil all the specified movements (within the boundaries of the scale). This problem is an accident of preservation: a given score with *gaps* happens to show downward movements out of balance with upward movements, or vice versa. To compensate we added a few additional intervals (in our test case, which had 60 melodic movements, we added two 'one-ups' and one 'two-up' to make up for too many downward intervals). These additions are justified because the actual piece would necessarily show a closer balance if we had it intact.

The compositional rules for method III are as follows:

Compositional rule 1: Use the following notes: [the notes used in the piece].

Compositional rule 2: Start with [opening note or interval where known, or a random starting note]; choose ending note at random.

Compositional rule 3: Construct the sequence of notes according to the following distributions: [the number of instances of each type of melodic movement derivable from the piece based on notes about which there is no uncertainty; for an example, see the counts for Seikilos above under method I].

Compositional rule 4: Do not repeat any note more than [the maximum repeats in a row in the piece].

Compositional rule 5: At the lowest note, go up or repeat in accord with rules 3 and 4; at the highest note, go down or repeat in accord with rules 3 and 4.

Compositional rule 6: Randomly match the words to the melodic strings 100,000 times.

APPLICATION OF THE METHODS TO SELECTED MUSICAL DOCUMENTS

We applied our three simulation methods to Greek musical documents where there is some question about whether patterns of PH accord are by design. Hence, we did not run simulations for documents that clearly manifest PH accord: the two Delphic paeans, the songs of Mesomedes (with the exception of Invocation of the Muse), *P.Oslo* 1413, ll. 15-19, g-m, *fr.* a, *P.Berlin* 6870 + 14097, *P.Oxy.* 2436, and *P.Mich.* 2958 ll. 1-18.

We also did not simulate for pieces that clearly give no indication of following the PH rule. Songs in this category offering five or more analysable words include *P.Vienna* G 29 825 a/b verso (2 of 8); *P.Zenon* 59533 (2 of 5); *P.Vienna* G2315 (Euripides, *Orestes*, 338-44) (3 of 7; also 3 of 7 when the strophe is matched to the same melody); and *P.Oxy.* 3704 *fr.* 1→ (2 of 5). We did do simulations for *P.Berlin* 6870, ll. 16-19 because its 0 of 9 looked as if it might be a case of *deliberate non-accord.*

With one exception (intended as an illustration), we did not run simulations for pieces containing fewer than five words susceptible of analysis for PH accord, since these sample sizes are too small for statistical analysis.

We gathered the results from the simulations in tables, such as the one shown in FIG. 1. This table gives results for *P.Oxy.* 1786, using method I, based on a confident reading of twenty words analysable for PH accord. The actual PH accord for these twenty words is 13. The table shows how often this '13 of 20' occurred randomly in the simulations. One finds 13 in the left-hand column and reads to the right. Thus, we learn that 13 (out of 20) occurred 10.176% of the time in the simulations. The other numbers in the left-hand column refer to other accord possibilities. Thus, we discover that in the simulations, 3 out of 20 resulted only .008% of the time, while 11 out of 20 occurred 19.105% of the time. The actual PH accord for *P.Oxy.* 1786, 13 of 20, correlates with a *p*-value of about 18%, given in the far right column as a decimal figure (.1818). The *p*-value for a particular number of accords, we recall, is the sum of the random frequency percentages for that number and higher. How often did 13 or more accords result from the random simulations using our twenty words from the confident reading and matching them to melody strings generated using method I? The answer – the *p*-value – is .1818 or roughly 18%.

P.Oxy. 1786 (13 of 20 PH accord) Method I, confident reading

Accords	Random freq. percentage	*P*-value
1	.0%	1.0
2	.001%	1.0
3	.008%	.99999
4	.087%	.99991
5	.445%	.99904
6	1.459%	.99459
7	4.105%	.98
8	8.44%	.93895
9	14.127%	.8541
10	18.3%	.71324
11	19.105%	.53019
12	15.734%	.33914
13	10.176%	.1818
14	5.31%	.08004
15	1.952%	.02694
16	.6%	.00742
17	.122%	.00142
18	.019%	.0002
19	.001%	1e-05
20	0.0%	0.0

FIGURE 1 (100,000 simulations)

Space does not permit presentation of all the tables (more than 60 of them). Instead, we provide below the information for each piece from the relevant lines of our tables for that piece. This includes our counts for PH accord and a list of the words on which these counts are based. Next comes a series of three random frequency percentages (RFPs) associated with the PH accord pattern of the piece and representing results from applying the three methods. Thus, rounded to the nearest tenth, the RFPs for 13 of 20 in *P.Oxy*. 1786 (confident reading) are 10.2%, 11.4% and 10.1% (the first of these can be found in Fig. 1). This means that 13 (of 20) accords occurred randomly 10.2% of the time using method I, 11.4% of the time using method II, and 10.1% of the time using method III.

Following the RFPs, we give the *p*-values for each piece, also as a series of percentages representing methods I, II and III. Where the *p*-values are above 5%, we also give in parentheses the threshold count where the *p*-values dip below 5% in our tables.

P.Ashm. *inv. 89B/31, 33* frr. *1 and 3 together*

PH accord: 5 of 5 based on the following words 1.1 ἰώι, ἄξιον; 1.2 ἰώ, πόποι; 3.11 ἀίσσων.
RFPs: 18.8%, 16.2%, 12.0%
P-values: 18.8%, 16.2%, 12.0%

We have taken *frr*. 1 and 3 together because they may belong to the same composition. This song illustrates the powerful combination of a high repeated-note percentage and a high proportion of two-syllable words. The repeated-note percentage is 48% and the ratio of two-syllable words to polysyllabic words is 3:2. Together, these features make chance accord more likely.

P.Ashm. *inv. 89B/29-32* fr. *15.i*

PH accord: 4 of 5 based on the following words: 15.i.1 Κύπριδος; 15.i.2 δρόμον, ἐπίκροτον; 15.i.3 κανεῖ (non-accord), ἔρωτι.
RFPs: 23.3%, 18.6%, 21.3%
P-values: 29.3%, 24.6%, 26.2%
(At 6 of 6 the *p*-values are: 6.0%, 6.0%, and 4.9%.)

Of the scraps in *P.Ashm*. inv. 89B/29-32, only *fr*. 15 col. i provides enough evidence for statistical analysis.[18] Readings for Κύπριδος, κανεῖ and perhaps ἐπίκροτον (which could have a melism on the last syllable) are somewhat uncertain, but the sample size would be too small for statistical analysis with a stricter confident reading of two or three words.

P.Berlin *6870, ll. 16-19 (*Ajax *fragment)*

PH accord: 0 of 9 based on the following words, all of which clash with the PH rule: 16 Αὐτοφόνωι, χερί, φάσγανον; 17 Τελαμωνιάδα, Αἶαν; 18 Ὀδυσέα, ἀλιτρόν; 19 ἕλκεσιν, ποθούμενος.
RFPs: 0.4%, 0.6%, 0.5%
P-values: 0.4%, 0.6%, 0.5%

In this remarkable piece, the melody goes *against* the PH rule a perfect 9 out of 9 times. Therefore, in simulating for this piece we formulated the alternative to the null hypothesis as the

[18] *Fr.*13.ii shows perhaps 3 of 3 PH accord, but this sample size is too small for analysis. Note that the section of *fr*. 15.ii that contains legible notation is not part of *fr*. 15.i but belongs to another piece.

possibility that the composer deliberately imposed a rule of non-accord. The results show that the probability of 0 of 9 accords is less than 1%, which supports the alternative hypothesis. Perhaps the composer, whether idiosyncratically or following a tradition of which we have no record, sought to express the pain of a woman's lament by distorting the natural melody of the words through a consistent inversion of the PH convention.[19]

Copenhagen inv. 14897
Seikilos Epitaph

PH accord: 8 of 10 based on the following words: ὅσον (non-accord), φαίνου, μηδέν, ὅλως, λυποῦ, ὀλίγον, ἐστί (non-accord), τέλος, χρόνος, ἀπαιτεῖ.
RFPs: 8.4%, 5.3%, 7.2%.
P-values: 11.1%, 6.6%, 9.4%
(At 9 of 10 the *p*-values are 2.7%, 1.3%, 2.2%.)

It has been a common assumption since scholars first observed melody/accent relations in ancient Greek musical scores that the Seikilos inscription manifests PH accord. But the *p*-values obtained through the simulations are large enough to cast at least some doubt on this *prima facie* impression. In view of this, it is worth recalling that Otto Crusius, who first observed melody/accent correlations in Seikilos, also remarked, 'Doch kann das Alles schließlich Zufall sein'.[20]

If the *p*-values for Seikilos are not low enough to make us certain that the pattern is by design, design is not thereby ruled out. (Here we must keep in mind that large *p*-values are not evidence favouring the null hypothesis.) Moreover, the *p*-values are not high and at least one is quite low. Furthermore, there may be sufficient indications in Seikilos' song that other melody/accent rules were followed (falling patterns with the circumflex, the sustaining of the pitch height of the melody after an oxytone) to encourage the conclusion that the composer also used the PH rule, since that rule seems always to be followed when the others are. A final judgement would require taking all of this evidence into account.

One additional consideration comes from a modified form of our method I simulations for Seikilos' song. We ran a second set of method I simulations, forcing an automatic non-accord for the first word of every random string in order to give the benefit of the doubt to the theory that the composer was operating with the PH rule but was willing to suffer a clash on the first word because he wished both to preserve the wording of his poem and to begin his melody with a conventional rise. By forcing an opening non-accord, we imitated this decision, causing 8 of 10 to be a little more frequent. As a result, the *p*-value associated with 8 of 10 in method I goes down from 11.1% to 5.9%.

Mesomedes (?), Invocation of the Muse

PH accord: 8 of 9 based on the following words: 1 Ἄειδε (non-accord), Μοῦσά, φίλη; 2 κατάρχου; 3 αὔρη, ἀλσέων; 4 ἐμάς, φρένας, δονείτω.
RFPs: 7.0%, 6.5%, 6.5%
P-values: 8.1%, 7.5%, 7.4%
(At 9 of 9 the p-values are 1.1%, 1.0%, 0.9%.)

[19] See the further comments on this piece in the discussion of the history of the PH rule below.

[20] Crusius (n.2) 173 (speaking of his impression that design was at work in relations of pitch height to accent in this piece and in the compositions of Mesomedes).

Invocation of the Muse shows only one clash, and it occurs as a result of an opening rise. Therefore, we used the modified version of method I described above in connection with the Seikilos epitaph, forcing an automatic non-accord for the first word with method I (but not with the other methods). The high repeated-note percentage of this song (39% – almost double the average) makes it easier for PH accords to occur by accident, which accounts for the higher *p*-values associated with 8 of 9 PH accord in the simulations for this song compared with the much lower *p*-values associated with 8 of 9 in, for example, simulations for *P.Yale CtYBR* inv. 4510, i.2-2.5 (Song 1) (see below).

P.Oslo *1413a, ll. 1-15, b-f* fr. *a*

PH accord: 25 of 31 (81%) based on confident reading comprising the following words: 2a νέφος; 2b νέφος (non-accord); 3a φθιμένων; 3b φαντάσματ';[21] 4 τροχόν, Ἰξείων; 5 ἐπί (non-accord), ποταμόν (non-accord); 6 φάσγανα; 7 ἔμολεν, θάρσει, τλήμων; 8 ἀνέβη, δ'ἐπί (non-accord), φέγγος, Ἀχιλλεύς, δειλαί; 9 προλιποῦσαι, γλυκερά, βαίνει, φωνή; 10 ἦχον, σαφῶς (non-accord), πᾶσα; 11 δεσπότι (non-accord); 12 ἐμοί; 13 Πύρρου, πέλας; 14 ἀόρατον, Αὐτός, τυχόν.
RFPs: 0.1%, 0.1%, 0.1%
P-values: 0.2%, .01%, 0.1%

PH accord: 27 of 36 (75%) based on expanded reading comprising the words above and the following additional words: 3a φαντάσματ' (non-accord); 4 ὑπό (non-accord); 9 Κἀμέ; 10 ἐπιγειγνώσκω; 11 κατέδυ (non-accord).
RFPs: 0.4%, 0.2%, 0.1%
P-values: 0.6%. 0.2%, 0.2%

Various cancelled and corrected notes, together with a second set of note symbols above the first set at points in ll. 2 and 3, led Winnington-Ingram to conclude that this fragment shows a composer at work revising his or her score.[22] If we accept this hypothesis and compare the original and corrected versions, they come out almost the same as far as PH accord. In l. 5 the deletion of two notes (O and Z) makes for accord in the word ποταμόν,[23] but the notes for l. 2b written above νέφος spoil the accord for that word in 2a (the putative original). In l. 3, the correction for φαντάσματ' in 3b almost certainly makes for accord, in contrast to the non-accord for that word in 3a, but there is an uncertain note in 3a that could affect accord. Other cases of possible note corrections and deletions do not affect melody/accent accord (or not enough information can be read from the notation or word in question to make a determination).

P.Yale CtYBR *inv. 4510, i.2-ii.5 (Song 1)*

PH accord: 8 of 9 based on confident reading comprising the following set of words: i.2 νάρκισσον; i.3 κρατήσω, τόξα; i.4 Κασταλίδων (non-accord); i.8 τέμπεα; i.9 μᾶλλον; i.10 Βωμόν, ἐγώ; ii.4 ἡδονάς.
RFPs: 1.2%, 1.1%, 1.2%
P-values: 1.4%, 1.1%, 1.2%

[21] We have included φαντάσματ' (3b) in the confident reading because it is hard to imagine that the missing note for the opening syllable was higher than a Z (*g*′), the highest note used anywhere in the fragment.

[22] Winnington-Ingram (n.2) 56-7.

[23] We follow Pöhlmann and West (*DAGM*, 124-5), who included these two notes that Winington-Ingram suggests have been deleted.

PH accord: 14 of 17 based on expanded reading comprising the words above and the following additional words: i.2 φαρία (non-accord);[24] i.4 ἄισω; i.5 γεύσομαι; i.6 μαντεύσομαι; i.7 παρθένε (non-accord), τοξοχαρῆ; i.9 πελάγους; i.10 πλήσω.
RFPs: 0.2%, 0.1%, 0.2%
P-values: 0.2%, 0.1%, 0.2%

Pöhlmann and West do not mark as uncertain the low note for the second syllable of ἄισω (i.4), but Johnson has a different reading (a high note, which makes for non-accord), so we have placed ἄισω in the expanded reading.[25] If we include ἄισω in the confident reading and follow the note reading in *DAGM*, we have 9 of 10 PH accord, which is associated with slightly lower *p*-values: 0.8%, 0.6%, 0.8%.

P.Yale CtYBR *inv. 4510, ii.6-10 (Song 2)*

PH accord: 5 of 5 based the following words: ii.6 Μουσικά; ii.7 κλαίει; ii.8 μυρομένη; ii.9 ὄρνις; ii.10 γυνή.
RFPs: 3.6%, 4.7%, 3.5%
P-values: 3.6%, 4.7%, 3.5%

P.Michigan *2958, ll. 19-26*[26]

PH accord: 6 of 6 on confident reading comprising the following words: 19 ἔπι; 20 γνώμην; 21 σαφῶς; 22 πάρος; 24 ἦλθε; 25 ταῦτα.
RFPs: 3.0%, 2.6%, 3.3%
P-values: 3.0%, 2.6%, 3.3%

P.Oxy. *4463*

PH accord: 6 of 8 (75%) based on the following words: 4 Βάκχαι; 5 μαινάς; 7 σφραγίς; 8 τοξότης (non-accord), Ἔρως; 11 κολακεύω; 12 δείξων; 15 μορφαῖς (non-accord).
RFPs: 15.9%, 10.9%, 15.1%
P-values: (not sig.), 14.0%, 20.0%
(At 7 of 8 the *p*-values are 5.9%, 3.2%, 4.8%.)

Adding the somewhat uncertain μήστρα (l. 2, non-accord) would only raise the *p*-values. Moreover, this effect would not be offset by reading Μουσῶν in l. 10 as an additional instance of accord. The net result of these two additions would be 7 of 10, which is a lower PH accord percentage than 6 of 8. Moreover, adding two more two-syllable words would modestly increase the probability of chance accord, causing higher *p*-values.

[24] The word is uncertain but the accent placement is not. We have either φαρία (vessel) or ἴα (violets). In both possibilities there is a clash according to the note readings in *DAGM*.

[25] See W.A. Johnson, 'Musical evenings in the early Empire: new evidence from a Greek papyrus with musical notation', *JHS* 120 (2000) 65.

[26] On ll. 1-18 and ll. 19-26 as separate items in *P.Mich.* 2958, see O.M. Pearl and R.P. Winnington-Ingram, 'A Michigan papyrus with musical notation', *JEA* 51 (1965) 179-95; *DAGM*, 142.

P.Oxy. *3161 recto* fr. *1*

PH accord: 9 of 12 (75%) based on the following words: 2 δρυμῶν; 3 θεῶι (non-accord); 4 διοίσειν; 5 τέκνον (non-accord); 6 τίνι, ταῦτα; 7 ἐμοί; 8 τέκνον; 9 βοή; 10 φωνήν (non-accord), τάχα; 11 Τηρεύς.
RFPs: 21.3%, 17.9%, 18.3%
P-values: 39.9% 29.2%, 30.5%
(At 11 of 12 the *p*-values are 5.4%, 2.7%, 3.1%.)

An expanded reading with ἐμόν (l. 8) would not significantly change the results here, but ἐμόν is included in the expanded reading for *frr.* 1-4 below.

P.Oxy. *3161 recto* frr. *1-4*

PH accord: 12 of 15 (80%) based on confident reading comprising the following words: 1.2 δρυμῶν; 1.3 θεῶι (non-accord); 1.4 διοίσειν; 1.5 τέκνον (non-accord); 1.6 τίνι, ταῦτα; 1.7 ἐμοί; 1.8 τέκνον; 1.9 βοή; 1.10 φωνήν (non-accord), τάχα; 1.11 Τηρεύς; 2.7 φυτόν; 3.2 κρίσις; 4.5 νήπιον.
RFPs: 9.9%, 8.7%, 7.8%
P-values: 14.9, 12.6%, 10.8%
(At 13 of 15 the *p*-values are 4.9%, 3.9%, 3.1%.)

PH accord: 19 of 26 (73%) based on expanded reading comprising the words above and the following additional words: 1.8 ἐμόν; 2.4 φαέθον or Φαέθον; 3.1 ἀπώλεσεν (non-accord); 3.2 ἀπόλοιτο; 4.2 πόσα (twice; both non-accord); 4.3 Νηρεύς; 4.4 ταφήν (non-accord), μετά; 4.7 ἔσχεν; 4.9 κατά.
RFPs: 9.0%, 7.0%, 6.4%
P-values: 17.3%, 13.1%, 10.8%
(At 21 of 26 the *p*-values are 3.3%, 2.3%, 1.4%.)

The original editor, M.W. Haslam, interprets the fragments of *P.Oxy.* 3161 recto as part of the same piece and concludes that '[t]he melody appears to have appreciable but not absolute regard for word-accent'.[27] Of 22 words, he finds only four that violate the PH rule: θεῶι (1.3), τέκνον (1.5), φωνήν (1.10), and ἔσχεν (4.7). Haslam's readings differ from those of Pöhlmann and West, who find six breaches.[28] We have included one additional breach in our expanded reading – ἀπώλεσεν in 3.1 because it seems doubtful on the grounds of melodic character and vocal technique that the melism (with its more quickly moving notes) is a leap of a sixth or more, which would then require a plunge of a seventh or more to the next note. But if this word is an instance of accord, the resultant 20 of 26 is associated with *p*-values ranging from 8% to 4%.

Since φαέθον might be φαεθοντιάς (or one of its forms), we have included it only in the expanded reading. But some might be more confident about the reading φαέθον (or Φαέθον). If we place φαέθον in the confident reading, we have 13 of 16, which gives *p*-values that are in the 9% to 6% range for the three methods.

[27] M.W. Haslam, '3161. Texts with musical notation', *P.Oxy.* 44 (1976) 63.

[28] *DAGM*, 178.

P.Oxy. *3161 verso* fr. *3*

PH accord: 3 of 4 based on confident reading comprising the following words: 3.1 γένος, Περσῶν; 3.2 'Αελίου; 3.3 βασιλέα (non-accord).
RFPs: 18.0%, 12.9%, 19.7%
P-values: 20.8%, 15.2%, 23.1%
(At 4 of 4 the *p*-values are 2.8%, 2.3%, 3.4%.)

PH accord: 5 of 6 based on expanded reading comprising the words above and the following additional words: 3.2 ἅλις, πατρός.
RFPs: 7.0%, 5.6%, 10.0%
P-values: 7.9%, 6.1%, 11.4%
(At 6 of 6 the *p*-values are 0.9%, 0.5%, 1.3%.)

P.Oxy. *1786 (Christian Hymn)*

PH accord: 13 of 20 (65%) based on confident reading comprising the following words: 2 σιγάτω, ἄστρα, φαεσφόρα (non-accord); 3 ποταμῶν, ῥοθίων, πᾶσαι (non-accord), ὑμνούντων, δ'ἡμῶν (non-accord); 4 χυἱόν, χἅγιον (non-accord), πᾶσαι, ἐπιφωνούντων, ἀμήν, ἀμήν (non-accord), κράτος, αἶνος; 5 πάντων, ἀγαθῶν (non-accord), ἀμήν, ἀμήν (non-accord).
RFPs: 10.2%, 11.4%, 10.1%
P-values: 18.2%, 21.7%, 18.8%
(At 15 of 20 the *p*-values are 2.7%, 3.9%, 3.3%.)

PH accord: 17 of 25 (68%) based on expanded reading comprising the words above and the following words: 2 ἠῶ (non-accord); 5 δόξα, θεῶι, δωτῆρι, μόνωι.
RFPs: 6.1%, 6.4%, 5.5%
P-values: 10.6%, 11.4%. 9.5%
(At 18 of 25 the *p*-values are 4.5%, 5.1%, 4.0%.)

The results for the confident reading argue against inferring the presence of design, and the results for the expanded reading do not provide sufficient evidence for a different conclusion.

OBSERVATIONS ABOUT THE SIMULATIONS RESULTS AS A WHOLE

Differences in significance of PH accord percentages
The simulations show that *chance* PH accord typically averages *above* 50%. For example, the random PH accord percentages at the 'bell curve peaks' for method I simulations based on pieces with word samples of five or more (thirteen pieces) average out to 58%. Of these peaks, the highest is 80% and the lowest is 44%, which shows how widely chance accord can vary from one piece to another. Moreover, the bell curves differ in shape from piece to piece and are often not symmetrical.

Accord percentages vary in significance (have different *p*-values) from document to document. For example, method I simulations for *P.Ashm.* inv. 89B/31, 33 *frr.* 1 and 3 show 80% accord (4 of 5) as the most frequent random pattern, occurring 38% of the time with a *p*-value of 57% (the piece has an actual accord of 100%). But in simulations for *P.Oslo* 1413a, ll. 1-15, b-f *fr.* a (confident reading), 81% accord (25 of 31, which happens to be the actual accord for the piece) occurs less than 1% of the time and has *p*-values under 1%. In fact, where 80% accord in three of our pieces is associated with *p*-values that do not support the conclusion that their composers have followed the PH rule, the 81% accord of the *P.Oslo* 1413a fragment is linked with *p*-values that support the inference that its composer did follow the rule. These comparisons illustrate how differences in the character of the pieces – word types, intervalic movement and repetition – affect chance accord. *P*-values go down as the average syllable count per multi-syllabic word goes up; *p*-values go down as the average size of intervalic movement goes up; *p*-values go down as the frequency of repeated notes goes down.

The history of the PH rule

In what follows, we regard *p*-values in the neighbourhood of $p < .05$ as sufficient to overcome the null hypothesis. We have confidence about the presence of design with *p*-values that are this low, and we begin to have doubts about the presence of design when the *p*-values get much above the 5% mark. The reason for this is simply prudence, and others are free to interpret the results differently. Again, no *p*-values argue for any degree of likelihood that the null hypothesis is true. The *p*-values express only evidence against the null hypothesis.

Greek songs earlier than the Delphic paeans (128/27 BC) show no evidence of melody/accent interconnection. At least one of these songs belongs demonstrably to a strophic composition, which could explain why it does not exhibit melody/accent accord.[29] As for the others, it has been suggested that some of them are probably also from strophic compositions[30] or that there was a practice in pre-Hellenistic times of disregarding the accent even in non-strophic compositions.[31]

Some have argued that *P.Vienna* G2315 (Euripides, *Orestes*, 338-44) shows the marks of at least some effort to conform the melody to the accents, even though it belongs to a strophic composition.[32] When we follow *DAGM* for note readings, we find only 3 of 7 PH accord for the antistrophe and get the same result for the strophe. Simulations are not necessary to know that this pattern provides no basis for seeing the influence of the PH rule.

The other pieces from Classical and early Hellenistic times are either too fragmentary for analysis[33] or also show PH accord percentages too low to raise any suspicion of design: *P.Ashm.* inv. 89B/31, 33 *frr.* 1 and 3 together; *P.Ashm.* inv. 89B/29-32 *fr.* 15.1; *P.Zenon* 59533 (showing 2 of 5 PH accord); *P.Vienna* G 29825 a/b recto (showing 3 of 3, which is too small a sample size for analysis; 5 of 8 if we include *DAGM* conjectures); *P.Vienna* G 29825 a/b verso (showing 2 of 8).

The only other fragment that may bear on the question of the use of a PH accord rule in Greek music before the Hellenistic period is *P.Berlin* 6870, ll. 16-19. It shows 0 of 9 PH accord, to which our simulations assign *p*-values under 1%, providing evidence that the composer deliberately set the melody against the accent. The tragic text of this document is usually dated to the Classical or early Hellenistic period. If we assume that the melody also stems from that time, we can reason as follows. For the composer's technique of inverting the PH rule for dramatic effect to have been meaningful, the PH rule must have already been well established at the time of composition. Hence, a dating of the song to Classical times (or perhaps even the early Hellenistic period) argues for the establishment of the PH rule in the Classical era. But the dating of the melody is very uncertain. It seems more likely that we have an old song text set to a new melody at a later time.[34] This possibility is consistent with the fact that the song was written down on the back of a Roman military document dating from the second century AD.

[29] Strophe and antistrophe carry the same melody. It would be very difficult to devise an antistrophe that carried accentual patterns suiting the melody of the strophe. See W.D. Anderson, *Music and Musicians in Ancient Greece* (Ithaca 1994) 95-6.

[30] West (n.2) 199.

[31] Pöhlmann (n.3) 81-2; cf. *DAGM*, 17.

[32] D. Feaver, 'The musical setting of Euripides' *Orestes*', *AJPh* 81 (1960) 1-15.

[33] *P. Leiden* inv. P. 510 (lines from Euripides, *Iphigenia in Aulis*); most of the fragments from *P.Vienna* G. 29825; the fragments of *P.Vienna* G 13763/1494; Epidaurus, *SEG* 30.390 (Hymn to Asclepius); *P.Berlin* 6870, l. 23 (but date uncertain).

[34] See West (n.2) 320-1.

Moreover, the melody is too high for a male actor's voice, which tells against the assumption that the song was composed in the Classical period, when male actors played female parts. Melodic features of the song also suggest a later musical composition.

All in all, there is no indubitable evidence that the PH rule was followed by composers before the second century BC. The first clear evidence of the rule bursts on the scene with the two exquisite Delphic paeans from 128/27 BC.

From the documents datable to the Roman period, we have perhaps eighteen songs (or fragments of songs) that offer sample sizes large enough for statistical analysis. The only songs datable to the first century AD show clear evidence of PH accord: the two songs from *P. Oslo* 1413a. The picture is somewhat mixed for the second century. The three songs of undisputed authorship by Mesomedes all show PH accord by design: Hymn to the Sun, Hymn to Nemesis and Invocation of Calliope and Apollo. Five other second-century songs also show PH accord by design: the two songs of *P.Yale CtYBR* inv. 4510; the two songs of *P.Michigan* 2958 (ll.1-18 and ll. 19-26); and *P.Berlin* 6870 + 14097. A question mark stands over *P.Oxy.* 4463 and *perhaps* also over the Seikilos epitaph and Invocation of the Muse (although evidence of other kinds of melody/accent correlation would probably overcome any doubt). *P.Oxy.* 3704 *fr.* 1→ shows no marks of design (2 of 5). None of the documents dated to the third century provide convincing evidence of having been composed with regard for the PH rule: *P.Oxy.* 3161 recto *fr.* 1; *P.Oxy.* 3161 recto *frr.* 1-4; *P.Oxy.* 3161 verso *fr.* 3; *P.Oxy.* 1786.

The preceding shows that the PH rule was used from the last part of the second century BC until some time in the second century AD. The rule may also have been used before 128/27 BC or after the second century AD, but our statistical simulations do not offer evidence supporting any confident conclusions about this.

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