Music Perception
Summer 1990, Vol. 7, No. 4, 423–434

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UNIVERSITY OF CALIFORNIA

Composers' Pulses: Science or Art?

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In this reply, I respond to Clynes's (1990) criticisms of my earlier work and raise a few questions about composers' pulses not addressed in his "guidelines." Although most of his criticisms are justified, they also reveal many unresolved methodological problems and a prominent role of subjective musical judgment in devising perceptual tests of composers' pulses. This makes the theory very difficult to test.

In the preceding article (Clynes, 1990), Manfred Clynes has provided a number of guidelines for the proper execution of research testing his theory of composers' pulses. In doing so, he has done a valuable service to those in the scientific community who are eager to conduct such research. However, the guidelines do not necessarily make it any easier for them.

Under Clynes's benevolent umbrella huddle many methodological criticisms of my experiments (Repp, 1989, in press a).[1] These criticisms are by no means unjustified, although they reflect Clynes's rather low tolerance for deviations from what he considers ideal conditions. Although I can readily concur with his demands for maximum accuracy and fidelity, I disagree with his implication that research that does not meet his stringent criteria is totally invalid and meaningless. If the extreme precision he demands is *necessary* to prove the composer-specificity of pulse microstructure, it must be a very fragile phenomenon indeed.

This apparent fragility may be contrasted with the relative robustness of the general and piece-specific perceptual effects generated by pulselike microstructure. As my studies have shown, pulse patterns resembling those postulated by Clynes for Beethoven, Haydn, Mozart, and Schubert are easily discriminated by listeners, even without extensive musical training. There was a reliable rank order of preference for the pulses, with either the

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1. He refers to an early abstract of my second study, a complete report of which is now forthcoming in this journal (Repp, in press a).

Beethoven or the Haydn pulse liked best, and the Schubert pulse liked least; and there were reliable differences between the pulse preference patterns for different compositions. On the other hand, despite some suggestive findings by Thompson (1989) and Repp (1989), no convincing evidence has been published so far that listeners react to these pulses in a composer-specific way.[2]

In this note, I respond to Clynes's criticisms. At the end, I raise several questions that have not been addressed in his guidelines and that are perhaps more important than some of the methodological details. (My headings echo those of Clynes's article.)

Production of Microstructure

PRECISION OF TIMING

Clynes states that "2-msec differences are already markedly noticeable in the musical context (Clynes, 1983, 1987)." It is not clear what psychophysical data this observation rests on. Perusal of the cited articles reveals no pertinent data; almost certainly, Clynes is referring to his own perception, as observed informally in his laboratory. As Clynes is both an experienced musician and a highly practiced listener, he may have acquired exceptional abilities of temporal discrimination. Ordinary listeners, even those with musical experience, are likely to be considerably less sensitive. Thus, for example, Halpern and Darwin (1982) found an average difference limen of 17.5 msec for 400-msec intervals presented in a rhythmic sequence. Schulze (1989), in a similar study, found values of 7–16 msec for 400-msec intervals, and 4–16 msec for 200-msec intervals, depending on the length of the sequence. Clarke (1989) reported that music students were unable to detect 10-msec differences reliably in a melodic sequence of 400-msec intervals and that even a 40-msec difference was difficult to detect when the interval durations were unequal to begin with. Finally, Sundberg (1988) referred to his own informal but extensive listening experience suggesting that timing perturbations must exceed 10 msec to be noticeable. Even though the conditions of stimulus presentation in these studies were not exactly those encountered in listening to composers' pulses, it seems nevertheless likely that typical listeners, even with musical experience, are a good deal less sensitive than Clynes implies. This hardly disqualifies them as subjects. Certainly,

2. A recent study by Clynes and Patinson, which improved on the stimulus materials of Repp (in press a), has obtained some positive results, particularly for a listener group composed of distinguished artists. A preliminary report of these data was presented in Clynes (1989) and in the oral version of that paper.

many listeners can appreciate a good performance of Beethoven, so why not the "Beethoven pulse"?

As a consequence of his assumption that listeners can distinguish timing differences as small as 2 msec, Clynes is suggesting that the temporal precision of the materials in my recent study (Repp, in press a) was insufficient. His calculations seem exaggerated, however. There was no cumulative error of any kind because the initial beats of successive pulse cycles were unperturbed and hence precisely isochronous. Also, different voices were always virtually simultaneous. As to temporal deviations within each pulse cycle, a certain amount of "jitter" was introduced by using a temporal resolution of 5 msec. The *maximum possible* rounding error in calculating temporal displacements of tones was thus 2.5 msec, and the maximum possible error in an onset-to-onset interval (if successive tone displacements were rounded in opposite directions) was 5 msec (and not 10–15 msec, as Clynes suggests). In fact, however, errors of this magnitude did not occur. The average absolute error in the pulse specifications was 1.48 msec; of 320 pulse parameters (20 pieces, 4 pulses, 4 beats each), only 8 exhibited a temporal distortion greater than 2 msec, and two a distortion greater than 3 msec.[3] The timing pulses used were thus highly *similar* to the models provided by Clynes and were probably indistinguishable from them for most listeners. Moreover, there was no relationship between the accuracy of timing pulse realization in individual pieces and the relative success of the "correct" pulse in listeners' judgments. Although greater precision is desirable for future studies, it seems highly unlikely that temporal inaccuracy was responsible for the negative findings in Repp (in press a).

AMPLITUDE RELATIONSHIPS

Clynes's concerns with regard to amplitude values are a different matter. Most of the important considerations discussed in his guidelines were not touched on in his earlier publications, and they present significant compli-

3. In terms of percentage values, the accuracy of pulse realization improved with pulse-cycle duration: The average absolute onset-to-onset interval error ranged from 0.31% to 1.21%, with a mean of 0.72%. It is conceivable that some additional error was introduced in realizing these specifications on my electronic piano. Clynes (1989) refers to measurements he conducted on my recorded materials that revealed timing errors of as much as 5–10 msec. Subsequent spot checks of my own confirmed occasional errors of this magnitude; however, they could easily be due to measurement error, because note onsets are difficult to determine precisely in an acoustic waveform. It might be noted in that connection that waveform measurements of a computer performance produced by Clynes on his equipment showed even larger timing deviations (Repp, in press b).

cations for tests of pulse microstructure. They concern resolution and range, compensating for changes in timbre, and adjustments for multiple voices.

As to resolution, I am not aware of any published studies that have determined perceptual thresholds for amplitude changes in a musical context (but see Nakamura, 1987). It seems, however, that the resolution of 0.27 dB employed by me (Repp, in press a) was entirely adequate, as it is well below the psychophysical intensity difference limen (Gulick, 1971). Also, extremes were avoided; in the total keyboard velocity range of 0–127, all tones fell in the range of 10–97 (10–77 for accompaniments, 30–97 for melody notes). No "strident distortion" was noted at the highest levels used.

More importantly, Clynes emphasizes that, on electronic pianos such as the Roland RD250S that I used (Repp, in press a), an adjustment must be made for the nonlinear relationship between perceived loudness and intensity, caused by changes in timbre. (Brightness increases with intensity.) I admit having overlooked the fact that Clynes's pulse specifications were developed for sinusoidal sounds only. In generating materials for me (Repp, 1989) on his own Roland sound module, Clynes used a "special nonlinear calibration" that, unfortunately, he did not describe in detail anywhere and whose significance eluded me until recently. The amplitude perturbations in my materials (Repp, in press a) therefore exaggerated the differences in loudness intended by Clynes's pulse parameters; by how much is not clear. Still, they were *similar* to the intended pulses in that they had the same ordinal amplitude relationships among the four pulse beats. Therefore, one should think that a somewhat exaggerated "correct" amplitude pulse would still be preferred over an exaggerated "incorrect" pulse.

Clynes also suggests that the amplitude pulse may have to be modified in response to the note density of multiple voices, "if this is appropriate." Although he seems to use this argument mainly in order to disqualify some of my materials that yielded negative results (see Clynes, 1989), and although I am not aware of any such adjustments having been made in Clynes's own computer performances so far, the comment has profound implications. As accompaniments can vary greatly in texture throughout a piece, such modifications could result in considerable alterations of the pulse structure from cycle to cycle. To the extent that a composer's pulse represents a distillation of that composer's preference for emphasizing certain beats, any particularly characteristic passage from that composer's music may require adjustments that effectively eliminate the pulse. Perhaps this is the way it should be, but the rules for these adjustments are far from clear and the qualification "if this is appropriate" is disturbing, as it introduces subjective musical judgment into the process.

STACCATO REALIZATIONS

The choice of staccato parameters is also an artistic one, and is largely independent of the pulse, although it may also interact with accent patterns. When introducing a timing pulse (i.e., varying onset-to-onset intervals), either tone durations or silence durations of staccato notes, or their ratio, could be held constant. I decided to hold tone durations constant (Repp, in press a); according to my analyses, the resulting confounding of silence durations (and occasional slight separation of originally legato transitions) did not have a demonstrable effect on the results. However, Clynes's procedure of holding silence durations constant and varying tone durations with the pulse is surely preferable, and keeping the sound/silence ratio constant would perhaps be an even better alternative. Clynes also mentions micropauses, whose introduction seems to be subject to artistic judgment and which result in local distortions of the timing pulse.

PITCH CRESCENDO

This feature, previously mentioned by Clynes (1983) and part of Sundberg's performance rules (Sundberg, 1988, Sundberg & Frydén, 1985), clearly distorts the amplitude pulse. It does not seem to have been implemented in Clynes's materials for Repp (1989). Moreover, Clynes suggests that different pitch crescendo functions may be required for different composers. This further complicates the picture.

PEDALING

While pedaling changes the durations and offset characteristics of tones, it leaves their onsets unchanged. It is not clear, therefore, why Clynes's pulse specifications should be invalid when the sostenuto pedal is used. This point requires elaboration.

Presentation to Subjects

REPRODUCING EQUIPMENT

Clynes's comments in this section are addressed squarely toward the insufficiencies he noted in my audio equipment (Repp, 1989, in press a). It is unarguably true that I would have used much better equipment, had it been readily available. The question is: Would it have made any difference? With respect to at least one factor, the reproduction of Dolby-recorded tapes

without Dolby, I am quite convinced that it does not affect listeners' responses substantially. This was verified by comparing different subject groups in Repp (1989), and by myself listening "blindly" to the tapes both ways (over earphones) and obtaining highly similar ratings. There is no doubt that listeners' differential responses to the pulses, including their piece-specific interactions, are highly robust across different sound-reproducing equipment, even if some loss of fidelity occurs. The composer-specific effects of the pulses, on the other hand, seem to be so ephemeral as to require absolutely optimal sound reproduction. It may be asked whether findings obtained under such idealized conditions have any practical value and whether they could ever be replicated.

ACOUSTIC ENVIRONMENT

Very much the same comments apply here. It should also be noted that several subjects in my studies listened with earphones on high-quality equipment, without giving more positive responses to the "correct" composers' pulses.

Musical Considerations

PARTS OF PIECES

Clynes's arguments here are interesting but can easily lead to an infinite regress, according to which only whole movements, or whole sonatas, or whole cycles of sonatas are sufficient to establish a context for the composer's pulse. In an earlier publication, Clynes (1983) stated quite clearly that the pulse needs to be "well initiated at the beginning of a piece" (p. 131). If the opening section, containing the major theme of a piece, does not sound good with the pulse, what will? By arguing in favor of entire compositions, Clynes seems to be suggesting an influence of *following* context on the judgment of the pulse at the beginning. Similarly, his criticism of my separation of the trios from minuets in Repp (1989) distracts attention from the largely negative findings for the minuets. Negative findings for the isolated trios may well stem from the reasons considered by Clynes; however, it cannot be argued that absence of the following trios was responsible for the poor results with the minuets.

Clynes's discussion of the "importation" of the pulse from earlier musical contexts into less characteristic parts of a composition (such as scales and passage work) is interesting and subject to empirical verification; however, it refers to a secondary effect, a kind of bias. The primary question is: Does the pulse fit this section or that? For example, my presentation of the isolated trios to listeners was meaningful because it established that the

pulses did not fit well in those musical sections. This result would have provided a sound basis for testing Clynes's claim that pulse appreciation improves in the context of a preceding minuet—if the pulses only had been more successful in the minuets.

ORNAMENTS

Clynes introduces another factor here that requires adjustment of the pulse parameters. It appears that the pulse interacts with all kinds of structural features of the score, according to principles that at present rest on musical judgment alone. It is difficult to see how the pulse retains its integrity under all these changes, and how an objective test could be devised. At the very least, extensive research would be necessary to determine first how to modify the overt microstructure to maintain *perceptual* invariance for a particular pulse pattern across various contextual changes.

PULSE CONFIGURATION

This is a central issue, and also a highly problematic one. Clynes states as facts that "the wrong configuration is noticeable as a major error" and that "the effects of the correct choice are so pronounced that it is not hard to make in most instances." Yet, there is no empirical evidence to support these statements other than Clynes's subjective experience. Psychologists like myself, who would like to avoid subjective choices in designing experiments, must consider this an empirical issue. In fact, Clynes has provided a general guideline in several earlier publications (Clynes, 1983, 1987): The basic pulse should occupy between 0.7 and 1.2 sec. These limits do not permit a doubling or halving of a given pulse cycle and, therefore, permit an unambiguous assignment of the basic pulse to a composition. In Repp (in press a), 5 out of 20 pieces deviated from this rule, 4 of them because Clynes (personal communication) advised me to change them.

In preparing materials for a recent, still unpublished study (see footnote 2), Clynes chose 12 of my 20 pieces and changed the pulse configuration in 8 of them (see Clynes, 1989). Besides introducing two hierarchical pulse levels, he also employed a degenerate 2-beat rather than a 4-beat pulse at the lower (faster) level in 7 of the 12 pieces. In all 12 pieces, the lower-level pulse cycle was shorter, and in 9 pieces the higher-level pulse cycle was longer, than the 0.7–1.2 sec recommended in earlier publications. Thus, unless the tempi were substantially different from the ones chosen by me, only 3 pieces had what I would have thought to be a "permissible" pulse. In addition, Clynes "phase-shifted" the pulse in two pieces, relying on his musical intuitions. Two Schubert pieces that had an uneven accompaniment and had not yielded good results in my study were designated "controls" (Clynes, personal communication; Clynes, 1989, mentions only one "con-

trol" piece). This multitude of subjective decisions makes independent replication of Clynes's results very complicated.

Clynes's comment that slow movements would provide an interesting testing ground for the pulses neglects to mention that the lowest level of the pulse is only sporadically represented in these pieces, in degenerate form (i.e., as a two-beat pulse), or not at all. In Repp (in press a), where only the lowest level was implemented, slow movements would clearly have been inappropriate. It is the higher levels of the pulse that become prominent in such pieces; these levels, however, are even more difficult to test because of the added freedom of amplitude "attenuation" (according to Clynes's musical judgment), and less convincing theoretical justifications for their presence.

TESTING MINUETS

Here Clynes seems to suggest, first, that minuets and other dance forms have an independent pulse of their own. He gives no indication of what that pulse might be and how it might combine with the composer's pulse. His warning, "Certainly, don't look for a linear combination!" seems gratuitous without further explanation. His second remark, that pulses with three components offer fewer degrees of freedom for differentiating composers than do four-component pulses, is preceded by his comment that a pulse with *two* components "can be very characteristic and effective"—an apparent contradiction. Clynes's third comment, that the relative appropriateness of the Haydn and Mozart pulses would be difficult to judge in early minuets by these composers, seems plausible on musical grounds; however, it does not take into account that these composers' pulses are in fact very different, and that the subjects in my (Repp, 1989) Experiments 2b and 2c did not judge them to be equivalent: The Haydn pulse was in fact rated much more positively in the Haydn Minuet than in the Mozart Minuet.

Clynes's disclaimer about the minuet materials used in Repp (1989) seems ex post facto, in view of the unsatisfactory results. It may well be that these materials tested the limits of the pulse theory; in fact, this is duly acknowledged in Repp (1989). However, if these pieces were a priori unsuitable for testing the pulses, Clynes should not have generated them. The fact that he did prepare them implies that there was a chance that the pulses would "work" in them, as they did indeed in the Beethoven and to some extent in the Haydn Minuet. But why did the minuets sound so awful with the Schubert pulse, and so unexceptional with the Mozart pulse? Appeals to a minuet pulse do not provide an explanation.

Expectations Concerning Subjects' Evaluations

Clynes's first comment, concerning effects of the isolated pulse, is right on target. However, his subsequent suggestion that "tests should be designed, weighed and tempered with musical considerations" is controversial. It would be preferable if good rules were available for pulse implementation and musical considerations entered only at the stage of interpreting the results. Clynes's assertion that "neutral" versions of pieces are in fact far from neutral requires elaboration to be meaningful. I agree that testing methods could be refined; unfortunately, Clynes did not follow his own suggestion of pairwise presentation in his most recent study (see footnote 2).

Experimental Studies to Be Done

Clynes's suggestion that the pulse parameters be varied in small steps rather than be grossly interchanged is excellent, provided that listeners can be found who are sufficiently sensitive to such small variations. However, he proceeds immediately to a more debatable statement: that the composers' pulses would be like "more meaningful 'islands' in a sea of relatively meaningless patterns." This argument forms the tacit basis for Clynes's stringent methodological requirements and for his tendency to declare results invalid if they were obtained with slightly deviant pulse patterns (Repp, in press a). Although his own tolerance as a listener for deviations from the ideal composer's pulse may be very low, a similar sensitivity cannot be expected from most other listeners. If there is any generality to the pulse concept at all, most listeners will show *similar* responses to pulse patterns *similar* to a given prototype, even if these patterns are discriminably different from the prototype. Also, different listeners should not be expected to have exactly the same conception of a given composer's pulse; thus, when considering group data, considerable statistical scatter is to be expected. Finally, there are hundreds of composers whose pulses are not yet known and may well fill the "empty space" between the few famous composers' pulses. That certain patterns are "meaningful" and others "meaningless" is a strong claim; moreover, it is not at all clear what is meant by "musical meaning." A more cautious approach would be to regard pulses simply as constellations of physical parameters that can fit a given musical structure more or less well. Changes in goodness of fit with continuous changes in pulse parameters are probably not nearly as categorical as Clynes suggests (except possibly for himself as a listener).

Questions Not Addressed in Clynes's "Guidelines"

Because Clynes's "guidelines" focus almost exclusively on chastising the methods of my earlier studies, they contribute little toward clarifying several important theoretical questions underlying the concept of pulse. Foremost among these is the issue of constancy and integrity of the pulse in the face of multiple sources of expressive variations in musical microstructure (see, e.g., Clarke, 1985). If the composer's pulse is to be thought of as a surface feature, it is not clear how it can be maintained for any length of time, except in artificial, impoverished materials such as the sinusoidal melodies used in the development of the pulse theory, or in exposed, relatively featureless stretches of music, such as scales. Clynes's discussion indicates that the surface microstructure needs to vary in response to many kinds of contextual variation, so the pulse pattern is in fact not constant, although it may exhibit *perceptual* constancy. However, if many other sources of expressive variation come into play that influence the surface microstructure, how is the pulse going to maintain its integrity? If it is to be thought of as an abstract *underlying* feature that, in conjunction with other sources of expressive variation, determines the surface structure of performed music, then this assumption needs to be made clear, and the rules by which the pulse combines with these other sources need to be investigated and made explicit. Conversely, one would be led to ask how listeners partition the complex surface variation of performed music into its underlying determinants, including the pulse.

These questions relate crucially to the necessity of demonstrating the presence of a composer's pulse in actual performances by great artists (cf. Repp, in press b). Clynes (1987) has explicitly eschewed measurements of human performances, arguing that the information obtained would not be precise enough. However, with the availability of instruments such as the computerized grand piano (see Palmer, 1989), these arguments are no longer valid. If the concept of composers' pulses is sound, it *must* be possible to demonstrate the presence of pulses in outstanding performances. It is important, therefore, to specify the criteria that should be applied in such studies. If the pulse is not evident on the surface, how should the surface structure be unpacked to get at the underlying pulse, if any? Presumably, the procedure will have to strip off variations due to other, structural sources; this will require a theory of structurally determined expressive variation, which Clynes has not provided nor even discussed in much detail (however, see Clarke, 1985; Todd, 1985).

Whether the pulse is a deep or shallow feature, its constancy over time is an essential attribute. Clynes justifies it by reference to his concept of "time-form printing" in the brain (see Clynes, 1983), the primary source for

which appears to be an abstract of a conference paper some years ago (cited as Clynes, 1977a, in Clynes, 1983). The concept of time-form printing, like that of the composer's pulse, is in need of better documentation and empirical validation.

Although Clynes often emphasizes that only musicians intimately familiar with a particular composer can realize that composer's pulse appropriately in performance, his obvious eagerness to share his discoveries with others through sound recordings and demonstrations at conferences shows a willingness to assume that there is a large group of listeners that can appreciate the pulses. This assumption should not be taken for granted, however. Perhaps, composers' pulses *are* ephemeral phenomena accessible only to a small group of highly sophisticated professional musicians (see footnote 2). If so, they command our respect but perhaps should be exempted from further attempts at empirical verification. In that case, the pulses are more art than science. However, it is premature to draw that conclusion.[4]

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4. My research discussed in this paper was supported by BRSG Grant RR05596 to Haskins Laboratories.

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