COMPLEX SOUNDS

Introduction

Three phases can be distinguished in the development of electronic music:

First Phase: Electronic music began with sinus tones and simple sinus tone spectra. The compounding of the spectra themselves and the way in which they were put together to form a composition kept to the rules of serial composition technique. The only complex aspect was what was serial and what could be controlled by the equipment available at that time: the number of partials in the sound. Formal complexity was taken over from instrumental music.

Second Phase: This is characterized by technical improvement and standardization of studios. The combination of the following pieces of equipment can be considered a norm:

generators for various wave-forms,
filters,
ring-modulator,
reverberation chamber.

The multifarious combination possibilities of this equipment result in multifarious, partly very complex sounds. These sounds were evaluated according to formal points of view, not according to ones of complexity.

Third Phase: At present its criteria are beginning to stand out. It is characterized by special equipment constructed by the studios themselves, and by automation and programming.

Automation: the use of punched tape and similar devices,
programming: the use of computers.

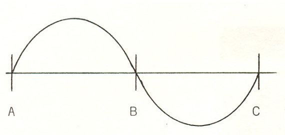
These technical devices make the complexity of sounds calculable, controllable and reproducible.

Instrumental music starts with the given instrument, producing particular sounds. – Electronic music starts with the idea of the sound which must then be realized. – It would appear to be sensible to think in degrees of complexity instead of in sounds. We must therefore try to give complexity a definition, to find its aesthetical significance and to provide production-technical equivalents.

Minimum complexity

What is complexity?

Let us consider the simplest example: the sinus tone. The figure shows one period. The amplitude climbs, reaches a maximum, falls, reaches zero, falls further, reaches a minimum., climbs and returns to zero (its initial position).



The two halves, AB and BC, appear to be symmetrical, although reflected by the time-axis.

The sustained sinus tone consists of a large number of repetitions of this period.

Let us call this period a "pattern". The pattern, apart from the division at B, is not compound. The division is symmetrical, both in time and with regard to amplitude.

The complete sinus tone consists of the literal repetition of this pattern; all periods are equal, all amplitude maxima are equal. We assume that the sinus tone represents a MINIMUM OF COMPLEXITY because

(a) the pattern is the simplest imaginable,
(b) the rule for succeeding patterns is also the simplest: all succeeding patterns are congruent to the first.

We derive TWO CRITERIA OF COMPLEXITY from this observation:

1st criterion: the nature of a pattern,

2nd criterion: the relationship between several patterns.

These criteria are not only applied in "microtime" (description of the sound), but also in "macrotime" (description of the form). In the first two phases of electronic music, complexity could only be controlled in macrotime; automation and programming also permit control of complexity in microtime.

We can divide the sinus pattern up into small time-steps and obtain a sequence of various amplitude values. The amplitude pattern appears to be much more complex. The truth is, however, that the individual amplitude values keep to a simple rule (the sine function); they moreover also show the symmetrical, reflected division. Not only the number of distinguishable parts are of significance for the complexity of a pattern, but also (and especially) the rule according to which they are distributed in the field of the pattern. The same applies to several patterns which form a higher unit.

The point

A "pattern" is defined by a number of distinguishable "points" forming an independent unit. If we divide a sinus tone into "samples", we obtain a number of amplitude-points distributed throughout the duration of the pattern – the period.

Points can be distributed regularly (in time, in amplitude, in any dimension occupied by the point).

Points can be distributed irregularly.

Distribution of points can either keep to a rule or be stochastic. The rule ensures periodic or aperiodic distribution.

The term POINT reminds us of impulses in electronic music or short tones in instrumental music (staccato, pizzicato). As we are attempting to apply the concept of complexity to all musical occurences, we must generalise the "point".

Two neighbouring points (in time) are separated by a distance. If we wish to observe a particular time-point, it doesn't matter whether the distance is empty or occupied (staccato or legato). Regarded in this fashion, the point is a "point of entry"; the distance between two points is called the "entry delay".

In polyphonic music a tone can start whilst another is being sustained. Something similar happens in electronic music (several loudspeakers, superposition of sounds). We define as a point *any relevant alteration in the sound field* serving to describe a pattern.

According to this definition we distinguish arbitrary and unarbitrary points. Arbitrary points can be seen from the score and technically reproduced. Unarbitrary points are the result of stochastic production conditions and cannot be reproduced.

The concept of the point reminds us of the so-called pointillistic phase of serial music. When we talk about points here, we do not mean the peculiarities of a certain musical style. The point which as a component of a pattern serves to define complexity is not always audible as such (point in microtime). However, as a unarbitrary point it serves to make musical structures reproducible and it is thus consistent in that it crops up again at a time when pointillistic music already belongs to musical history. In both cases, however, it denotes the starting position of musical rationality.

Horizontal/vertical

Several points, together forming a pattern, are distributed exclusively in time ("horizontal complexity"). Points coinciding in time effect a joint alteration in the sound-field and are therefore regarded as one point.

On the other hand, we distinguish several components in sound which sound simultaneously ("vertical complexity"). It is important not to confuse these two phenomena of complexity.

For this purpose we distinguish the two concepts
PHYSICAL COMPLEXITY - AESTHETIC COMPLEXITY

Physical complexity primarily means something to do with the horizontal distribution of amplitude values, thus describing a sound's waveform. It also serves to describe all technical processes performed in realising an electronic piece.

Aesthetic complexity means the differing aspects which the listener distinguishes in a piece or sound, whether horizontally (as a sequence of events) or vertically (as simultaneity of events).

Physical complexity, then, indicates the nature of the sound, or what procedures result in the sound's nature. A physically complex sound is not necessarily aesthetically complex too.

Physical complexity can occur both horizontally and vertically, the latter manner being when sounds are superposed. If two points coincide in time they are physically regarded as one point, although they can by all means be distinguished aesthetically.

Aesthetical complexity tells us more about the listener than about the sound. It is a formal criterion. This is why aesthetic complexity does not always correspond with physical complexity.

We are aware of aesthetic complexity in both a sound and a sequence of sounds. It tells us nothing about the physical equivalents: whether it is based on single or coinciding points.

It can therefore be seen that physical complexity is not identical with horizontal complexity, and aesthetic complexity is not identical with vertical complexity. It is especially aesthetic complexity that embraces simultaneity and succession, whereas physical complexity deals mainly with horizontally distributed points.

The Field

In the section on "Minimum complexity" we distinguished the characteristics of a single pattern from the ratio to one another in which several patterns are. We shall now deal with the characteristics of a single pattern and attempt to define it more precisely.

A pattern consists of "points" (compare "The point"); points can be distributed regularly or irregularly (perhaps obeying some rule), points are important changes in the sound field. We can say in general that points are "scattered" in a pattern.

When we speak of a particular parameter, we call the pattern belonging to it a field, or more precisely, a *parameter field*. A parameter field is defined by its limits (limit values) and by the characteristic distribution (scattering) of individual parameter values inside the limit values. For the scattering we require a particular "number" of parameter values to be scattered; scattering can ensue under restricting conditions. The "restricting conditions" are that neighbouring values must be at a given shortest distance apart, or that together they should form an arithmetic or geometric series (given lattice). – Scattering within a parameter field is called "selection"; the selection indicates which parameter values are available within the pattern.

The selection tells us nothing about the temporal sequence of the parameter values in the pattern. For this purpose we define a *time field*, which is vertical with regard to the parameter field. The time field is also determined by limit values, number of time values and perhaps by restricting conditions. We call the distribution of the parameter values among the given time-points "permutation"; permutation indicates the order of the parameter values in the pattern. If the time field contains fewer points than the parameter field, not all the parameter values can be used; the principle according to which the parameter values were scattered cannot be expressed completely. If the number of points is the same in both fields, we have the "serial" case. If there are more time-points than parameter values, the latter must be repeated.

A field thus consists of a parameter field and a time field and is therefore referred to as the *parameter/time field* (Fig. 1).

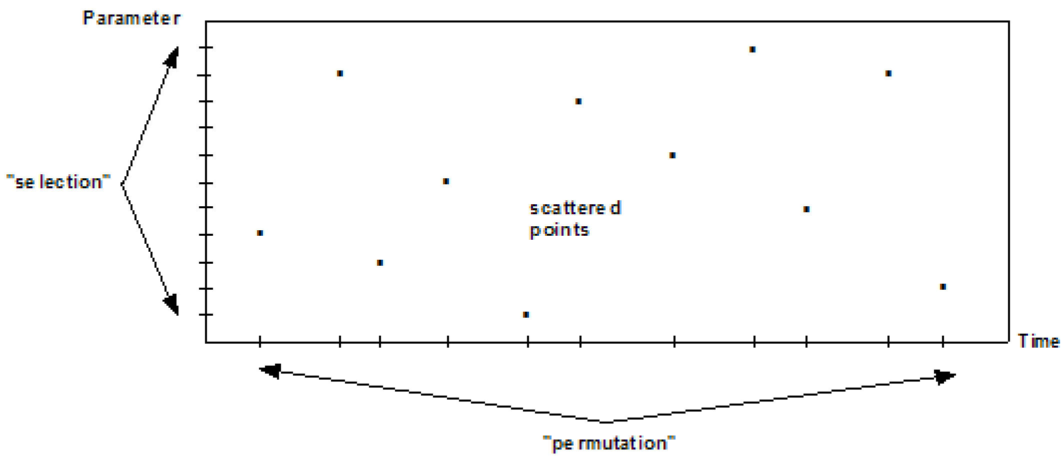


Fig. 1 – The parameter/time field

The Structure

The "parameter field" only describes the distribution of a single parameter. But since a pattern merely contains points which indicate a change in the sound field, any parameter or any combination of parameters can change per point. There are always several parameters in a musical form-unit.

There is a parameter/time field for each parameter (for example timbre, pitch, volume, locality); the various parameter/time fields are superposed to form a *structure*. The various time fields are also superposed – of course they must all be of the same length. The result is a *common time field*.

If the various time fields have been separately defined, time-points can coincide after superposition. At such places several parameters then change their value simultaneously. But time-points can be such close neighbours in the common time field as to render an instrumental performance impossible, or an electronic realization no longer able to be differentiated by the ear.

In order to meet this danger it is recommended first to define a common time field which contains permutation possibilities for all parameters concerned. For each individual parameter a selection may be made from the points of the common time field; it is not necessary for each parameter to change at every time-point.

In accordance with this construction we obtain the *structural characteristics*:

common time field or independent time fields,
selection of points of a common time field per parameter,
Number and distribution of time-points at which several parameters change,
characteristic distribution per parameter field,
characteristic permutation per parameter in time field.

If only one single parameter value is available for a parameter (fixed parameter), the structure receives a *common characteristic*. This term is of course ambiguous: we shall also have to speak of common structural characteristics when we compare several patterns.

SUMMARY
Every complete musical form-unit is called a sound field.
Every audible alteration in the sound field occurs at a particular point in time.
All time-points at which an alteration in the same parameter occurs result in the time field of the relevant parameter (distribution of the time-points within given time limits) and also in the permutation of the parameter values.
The parameter values are scattered in the respective parameter field and thus represent a selection from the continuum of all conceivable parameter values.

The setting up of a field (parameter field, time field or parameter/time field) is a preparatory action and merely tells us what part each parameter will play in the structure.

If several parameter fields are superposed to form a structure, dominating characteristics can occur which encumber or prevent the perception of other parameters. It is therefore sensible to arrange the parameters concerned according to their hierarchy, so that any "dominants" (main parameters) allot an unambiguous function to the single structure in a sequence of several structures.

As a rule, fixed parameters recede from other parameters which change frequently.

General Complexity

Complexity occurs if relationships prevail between the points of a parameter field or time field or a structure. These relationships are either produced by the composer or perceived by the listener, according to the aspect from which we look at the subject. The difference between physical and aesthetic complexity (compare "Horizontal/Vertical") becomes clear if the following four combinations are compared:

(1) Composer produces relationships,
Listener perceives these relationships;
(2) Composer produces relationships,

Listener does not perceive these relationships;

(3) Composer does not produce relationships,
Listener does not perceive relationships;

(4) Composer does not produce relationships,
Listener does perceive relationships.

Relationships can be produced or perceived within a parameter (by comparing the alterations in the same parameter), but also between two (or more) parameters. In this case we compare the alterations of the one parameter with those of the other.

Here we find a *point for point* dependence, such as the longer the softer, or a combination of clearly marked parameter/time fields, such as rising pitch and volume fluctuating around a central point.

We shall speak of higher complexity if the individual values have many relationships to one another, and of low complexity if only a few relationships are clear.

We can observe complexity:

(1) in a single parameter,

(2) (a) between two (or more) parameters of a form-section,
(b) between all parameters of a form-section,

(3) between several form-sections.

COMPLEXITY IN A SINGLE PARAMETER (example: pitch)

(a) Selection

Limit values, number of elements and manner of distribution must be defined; various possibilities are shown in Table 1.

Minimum complexity would result from the constellation

Limit values 1:1, Number: 1 the result is a single tone, which can only be repeated. A variant could be:

Limit values f:g, Number: 2 the result is two tones somewhere between f and g (depending on the *distribution*). According to the mode of permutation unexpected group formations could occur.

The first case (in table 1) also represents minimum complexity, being measured by the chromatic scale. The octave (1:2) is divided into 12 equal parts, each semitone occurring once; as long as this scheme is adhered to, nothing "happens". The reference system is important for the determination of complexity, so to speak the complexity 0 against which the constellation of parameter values stands out.

What cases 1, 4 and 6 have in common is that 12 pitches occur in an octave. Whilst there were only 12 possible pitches in the first case (distribution by $\sqrt[12]{2}$), there are 24 in the fourth and an unlimited number in the sixth case. This causes irregularity of distribution to increase, and it is more difficult to recognize the formation rule. In other words, the degree of surprise increases.

	Limit values	Number	Distribution
1	1 : 2	12	$\sqrt[12]{2}$
2	1 : 2	7	$\sqrt[12]{2}$
3	1 : 4	12	$\sqrt[12]{2}$
4	1 : 2	12	$\sqrt[24]{2}$
5	1 : 4	7	$\sqrt[24]{2}$
6	1 : 2	12	aleatoric

Table 1

Similar irregularities occur in the 2nd case (7 pitches from 12), in the 3rd (12 from 24) and in the 5th (7 from 48). The second case is interesting because distribution can turn out to be very asymmetric (e.g. 1 2 3 5 6 8 12). This impression would be even stronger if 14 tones were chosen from 24, such as 1-6, 8-12, 13, 15, 23. Here we would make a clear distinction between the two octaves; the lower one would be practically completely occupied, whilst only a few would be in the upper octave and would have the effect of being unexpected exceptions.

(b) Permutation (distribution in time)
Here, too, we can make a table in order to demonstrate a few possibilities (Table 2).

	Limit val-ues	Number	Distribution
1	1 : 8	12	$\sqrt[4]{2}$
2	1 : 8	7	$\sqrt[4]{2}$
3	1 : 4	12	$\sqrt[6]{2}$
4	1 : 4	24	$\sqrt[4]{2}$
5	1 : 8	12	aleatoric
6	1 : 1	1	–

Table 2

In the 4th case repetitions are provoked (24 values from 8 possible ones), in the 2nd (the same as the 2nd case in Table 1) a small degree of uncertainty arises because of the selection (7 from 12). The only differences between the 1st and 3rd cases (12 from 12) are the size of the intervals ($\sqrt[4]{2}$ and $\sqrt[6]{2}$) and the total ambit (3 octaves, 2 octaves).

(c) The parameter/time field

There are several possibilities of making any selection with any permutation. It is conceivable that one and the same selection could be permutated in various manners, that various selections could be permutated in the same manner or that selection and permutation could be changed every time. The field variants could then be linked to the unchanging variant of another parameter, etc.

When a parameter field is combined with a time field, it must be noted that the "number" in the time field determines the ultimate compass. According to whether the "number" in the parameter field is smaller or larger there will be repetitions or additional gaps in the parameter if the numbers are not exactly divisible by each other (parameter number equal to time number).

COMPLEXITY IN A FORM-SECTION

The complexity of sounds or sequences of sounds is not an absolute criterion. If two sounds are in succession, relationships occur which are more or less complex.

Sounds which are in themselves richly organized (Fig. 2a) produce more relationships than poor ones, and as far as that goes a sound is in itself complex, complex with regard to its assembly from several parameter/time fields.

If two complex sounds which can hardly be distinguished from each other are in succession (Fig. 2b), a non-complex relationship occurs. Two noncomplex sounds cannot be in complex relationships. (Fig. 2c)

Complexity occurs either *directly* or *indirectly*.

Direct comp1exity is observed if two sounds in direct succession, or partly or completely -verlapping, are compared (Fig. 2d).

In order to become aware of the complexity it is necessary for these sounds to be complete in themselves: not too long and with a recognizable beginning and end. The more sounds are allowed to interpolate, the more difficult it is to recognize the relationships between two particular sounds (Fig. 2e).

Indirect complexity can be observed if several sounds comprising a recognizable form-section are compared (Fig. 2f).

Listening (especially repeatedly) results in a kind of perception diagram: the entries of the sounds and thus their distances apart in time are registered on the time-axis, and the varying complexity of their relationships is registered vertically. In other words, the sounds are in varying relationships to each other, the "membership" of the same form-section, however, being common. The complexity of the individual sound is as it were its deviation from the average complexity of the whole forur-section; the complexity of the relationships between two sounds is their difference. Recognition of average complexity, in reference to which all relationships must be heard, occurs in stages; it increases with each further sound of the form-section. (Fig. 2g)

The "correctness" of the order of the sounds in this form-section could be measured by the extent to which this order encourages or prevents recognition of "average complexity".

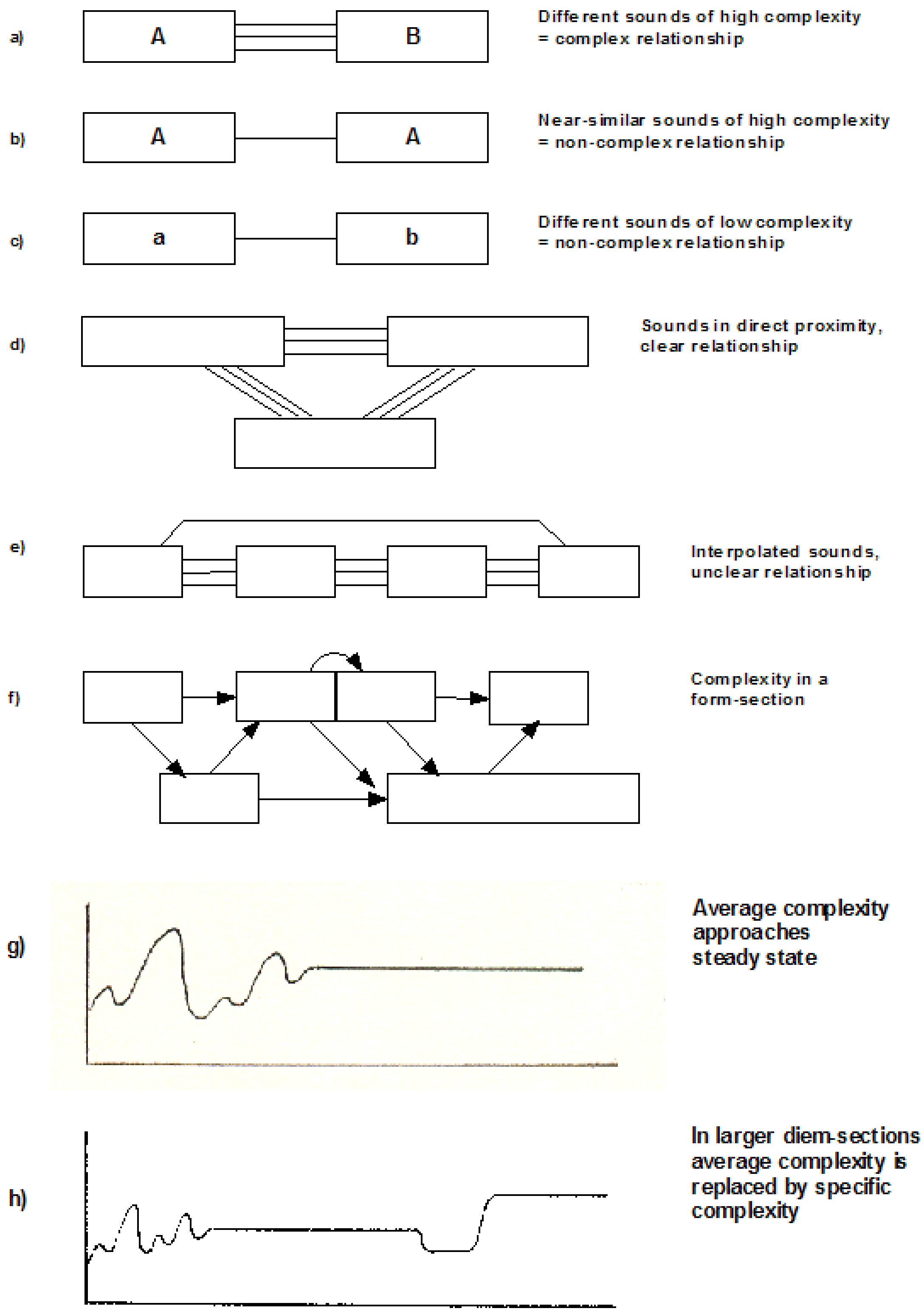


Fig. 2 – Complexity in several form-sections

COMPLEXITY IN SEVERAL FORM-SECTIONS

Perception of sound-complexity depends on time: we only hear the complex relationship between two sounds if we remember both of them. Every sharp contrast interrupts our awareness of the respective average complexity. If the original pattern is not returned to after the interruption by the contrast, a new average value is approached: a new form-section occurs for the listener.

In the same form-section the memory of how it began, and thus the perception of complex relationships, fades; the "average complexity" is modified with each sound of the form-section all the more strongly, the longer the form-section lasts. The average complexity ultimately fades from our consciousness, new sounds are no longer compared with past ones, structural hearing is replaced by pointillistic "listening along".

For "structural listening", then, the duration of a form-section in which all events are to be measured by an average complexity is limited.

Form-sections in their entirety only have relationships in outline: by similarity or contrast. Awareness of similarity is promoted by "leaving" similar parameter-fields "alone". The greater the number of parameterfields that change, the sharper is the contrast.

A relationship between form-sections, however, occurs when the similarity is brought about by the permutation of structure characteristics instead of by vague associations. Form-sections then become various aspects of one and the same thing which can only be completely recognized when all its aspects are perceived.

Common characteristics

If we compare two or more structures (compare "The structure"), we notice differing or similar characteristics. The characteristics of a single structure can be determined in two ways:

(a) by the combination of several parameter/time fields (compare "The field"),

(b) by the transformation of a given structure (compare "Transformation").

Prominent characteristics of a structure can be caused by noticeable characteristics of a single parameter, e.g. significant formulation of the pitch-flow or of the rhythm ("main parameter"). The characteristics of all the parameters can also complement one another in such a way that the structural characteristic cannot be traced to any particular parameter.

An important means of placing structures in reference to one another are *common characteristics*. Common characteristics occur (like the prominent characteristics of a single structure) either during sound production or during the transformation of the sounds.

SOUND PRODUCTION

During sound production common characteristics occur

- because of equal structure duration,
- because of the distribution of the elements (pitches, durations, volumes) in the same range, especially if the selected range is clearly contrasted against the entire available range,
- because of an equal degree of aperiodicity in the distribution of the elements.

Equal structure duration only functions as a common characteristic if it is noticeable as one, e.g. a short duration whose repetition is heard immediately. The common characteristic of duration is also clear if the durations of the other structures not belonging to the group with common characteristics clearly deviate from the *common* duration. Of course the common duration is not easily perceived in overlapping structures.

It is not necessary to give all parameters similar characteristics. If equal duration as a common characteristic has a grouping effect, the other parameters can be articulated in a different way each time. The more parameters have similar characteristics, the more strongly the structures refer to each other; but fewer means remain by which the differences between the structures can be worked out.

If the elements are respectively *distributed in the same range*, the number of elements and the manner in which they are distributed play a subordinate role. The only important thing is that the elements occupy the range to such an extent that the range appears as such, and that the entire range is a clear contrast to the "ambit" (the largest possible range). The number of elements and the manner in which they are distributed can then serve as variables. Here, too, the *same range* can be defined for one parameter, but also for several ones.

The *same degree of aperiodicity* must of course also be different from its surroundings. If the surroundings (the structures with non-common characteristics) are characterized by a medium aperiodicity, the *same degree of aperiodicity* should be especially *regular* or especially *irregular.* In this case it is not necessary to define a same range. The three criteria just mentioned can in any case be combined to make the *structures with common characteristics* form a stronger contrast to the rest.

SOUND TRANSFORM4TION

During sound transformation common characteristics are caused by the formation of variants because of similar operations in the existing structure. This can happen by means of transpositions to various pitch-steps, by means of ringmodulation with various signals, by means of chopping at various speeds, by means of filtering (various band-widths or the same band-width in various frequency ranges), by means of various envelopes, etc. Of course these transformations may be combined at will.

It is important that the transformation applies to the given structure as a whole, that it brings about an audible alteration, but leaves the given structural characteristics so intact that the resulting structures can still be referred to one another.

For the formation of variants by means of transformation it is also important to define the given structure unambiguously in certain parameters (e.g. pitch-flow, rhythm, etc.), and to place the kind of transformation in sensible reference to the structural characteristics. For instance, there would not be much sense in fixing the given structure in only one single parameter and then altering this very parameter by transforming it to unrecognizability.

If the common characteristics are ones of *complexity,* the formation of variants should also be in the field of complexity during sound production or transformation. Although compositional or machine-produced variants primarily alter the configuration in certain parameters, there is at the same time a change of complexity (unless simply one tone sequence is replaced by another, there being the same number of tones in the same range). One should therefore attempt to alter the configuration in a parameter in such a way that at the same time a proportional alteration of complexity occurs. Here a distinction could be made between "quantitative" and "qualitative" alteration of complexity:

quantitative alteration: increase or decrease of the degree of complexity,
qualitative alteration: alteration of the configuration with the same degree of complexity.

Degrees of alteration

Another means of determining the relationship of structures to one another is the "degree of alteration". This however only designates the relationship between two structures, whereas "common characteristics" can be shared by several structures.

The "smallest" degree of alteration might be designated by an ensuing structure differing from the first structure in only one single parameter, and that to such a small degree that the alteration is only just audible. If a parameter does not change, this does not mean that its configuration has to be repeated literally. It would suffice to preserve the average complexity and merely to vary the configuration "qualitatively" (compare "Common Characteristics"). However, the parameter responsible for the alteration would have to leave this frame and contrast to the others by means of a "quantitative" alteration of complexity. Here the "degree of alteration" is not in opposition to "common characteristics"; in each single case it would have to be decided as to whether structures should be *similar* (because of common characteristics) or *different* (because of a degree of alteration).

The "largest" degree of alteration might be designated by all parameters altering to as great an extent as possible, i.e. changing from one extreme to the other. This presupposes all parameters already to be in an extreme state in order to bridge the greatest possible distance to the other extreme. In this case the degree of alteration would have the exactly opposite effect to that of common characteristics.

Working with degrees of alteration is according to the old serial idea of leaving nothing unchanged and of arranging all alterations in steps and presenting them in particular orders ("rows"). Common characteristics, however, originate in the later idea of group composition, in which an attempt is made to form several events into a larger unit, which in its turn can then function as an element of a "row". Both aspects could be combined in such a way that several structures respectively form a group because of common characteristics; this group would differ from the following one because of a particular degree of alteration. Of course, here attention would have to be paid to the relationship between group and entire form. For if the "entirety" and the "parts" are to be distinguished from each other, the parts must be small enough with regard to the entirety; in other words, only "a sufficient number" of parts can be understood as a whole.

The area between the smallest and largest degree of alteration might be subdivided into steps. If five parameters are to be distinguished and each parameter is to be presented in five guises (alterations), it might be obvious to distinguish 25 steps. Of course these steps differ quantitatively from one another, so that the difference between alteration degrees 1 and 2 could be heard most clearly, and the difference between degrees 24 and 25 hardly at all. It is therefore recommended to make a selection, e.g. 2 4 6 10 16 25 or 2 3 4 5 6 8 10 13 16 20 25.

An essential characteristic of the degree of alteration is its interpretability. If we expect two successive structures to differ by the degree of alteration 1, it remains to be seen which parameter is to alter by this degree. The higher the degree of alteration, the larger the interpretation's range.

Example:

degree of alteration 2: *either one parameter is altered by 2 steps,*
or two parameters are altered each by 1 step;

degree of alteration 3: *either one parameter is altered by 3 steps,*
or three parameters are altered each by 1 step,
or one parameter is altered by 1 step and another one by 2 steps.

When we were considering the complexity of the relationships of several structures to one another, we were able to reduce minimum complexity to common characteristics. However, degrees of alteration cause stepwise contrast and thus an increase of the relationship's complexity. A larger degree of alteration will without doubt result in a greater degree of complexity. But greater degrees of complexity can be interpreted in many ways. If we want to realize alteration degree 5 and only consider the extreme cases, we can alter one parameter by 5 steps or each of the parameters by 1 step. Although the resulting structure in the former case might be much more complex than, and in greater contrast to the given structure, the complexity of the alteration in the second case would be greater.

Working with degrees of alteration appears to provide us with good control over complex relationships between structures. This control is however only quantitative. Following such degrees of alteration guarantees neither that the listener perceives the degree of alteration, nor that he is aware of its complexity. However, if we want to judge acoustic phenomena with regard to their physical or aesthetic complexity (compare "Horizontal/Vertical"), evaluation of the degree of alteration and its complexity can prove a means of doing so.

Permeability

In our considerations on the complexity of musical structures we have made a distinction between

(a) the complexity of a structure itself and

(b) the complexity of the relationship of several structures to each other.

In (b) we primarily mean structures which succeed one another so that a kind of tension results – as it were at the point of contact – a tension which we call complexity, or attempt to describe in terms of complexity.

Another situation occurs when structures overlap. In many cases the complexity of the individual structure will barely be heard; this also applies to the complexity of the relationships. But it will be all the more easy to perceive the characteristics of the overlapping structures, the more clearly they differ from one another. It is best to make these differences in three classes:

(a) FREQUENCY. Every structure has its own frequency range; the frequency ranges do not overlap. – If the frequency ranges come into contact with each other, the structures will have to be made to contrast with each other in another class.

(b) TIMBRE/RHYTHM. If both structures occur in the same frequency range, they can be distinguished by contrasting timbres: e.g. harmonic spectra against noises. The difference can be emphasized further by differing rhythms: e.g. a slow passage in one timbre range against a rapid passage in another.

(c) CONTINUITY. Structures separate if one of them consists of continuous sounds and the other of single impulses or short groups of sounds.

If overlapping structures contrast in this fashion, the overlapping is heard as such; the complexity of every single structure becomes clear, and also the relationship of the structures to each other. The contrast in one of the classes mentioned is in many cases a contrast in complexity.

If there is no such distinction, overlapping structures are in danger of coalescing and resulting in a uniform structure which can not be heard as having been put together from layers. We call such structures "permeable" structures. According to whether structures should coalesce or not, provisions should be made for a clear contrast between them, or for their being characterized in all parameters if possible by similar characteristics.

The result of overlapping permeable structures has its own complexity. Of course, this does not occur merely by means of addition. Because of the fact that the characteristics are in the same range, the second structure can be said to occupy the vacant positions in the first one (compare complementary rhythms in classical form study). Complexity then tends rather to be rounded-off or completed than increased. However, the more the overlapping structures differ from each other, the more they are perceived as overlapping, causing an increase in complexity, as much if "new" material being added to the first structure as the degree to which the second one differs from it. Finally, if structures only overlap in the technical sense but are heard as clearly differing ones, the complexities also remain separate: coalescence to form a greater degree of complexity does not occur, what *does* occur is a "formal" complexity: the structures enter a simultaneous relationship, the difference in their complexity is perceived directly – in contrast to structures which succeed each other, and where memory must place the complexities in reference to each other.

Permeable structures are more important for the form than for the production of material. It is not important to the listener whether a structure is produced as a whole or put together from two permeable structures, unless subsequent superposition of two individual structures, or subsequent separation of a permeably constructed structure, fulfil a function in the form. This impression can easily be brought about if the permeable structures enter in succession and then stop in the same order. At the places where the structures penetrate each other they exchange, as it were, their characteristics; it can then be seen that each structure is put together from individual characteristics (parameters), and that this combination is variable.

At the same time, however, permeability demonstrates that the structure, in spite of its addition from parameters, is not a total. In the permeable relationship of several structures to one another it is not the individual characteristics that coalesce but the structures as a whole. Permeable structures can therefore serve as an important link between the serial parameter definition and perception of a structure as *Gestalt.* For as long as structures succeed each other and change in their parameters step by step, attention is directed to the individual parameters, all the more strongly, the more striking the alteration of an individual parameter is in contrast to others that remain constant. Permeability then does not only coalesce several structures, but also – as formal side-effect – the parameters of each single structure.

Susceptibility

We have considered structures succeeding each other under the aspects of "common characteristics" and "degrees of alteration". In the case of simultaneous structures it can happen that they coalesce indivisibly – "permeability". A second phenomenon which can be observed when two (or more) structures occur simultaneously is called "susceptibility". This characteristic describes more the formal reciprocal relationships, whereas permeability can ignore the difference between the coalescence of sound and form: if two structures coalesce, they do so with regard to both aspects.

Susceptibility does not mean that two structures coalesce, neither does it mean that they "cover" each other; it does not even mean that they are transparent with regard to each other. Susceptibility means that two structures complement each other, interpret each other, that the one structure articulates the other in a characteristic manner. This capability of articulation is mutual, and not fixed in time. Susceptibility is thus a characteristic of aleatoric structures.

Structures which are to be susceptible to one another do not have to be incomplete, or as it were musically half-finished. They should be characterized by irregularly distributed combinations of similar elements. "Similar elements" are important for the structure, since structures could otherwise not be distinguished from one another. The irregularity of distribution provides for the articulative play of the parallel structure.

The penetration of two susceptible structures could result in a kind of coalescence (and dealt with under the aspect of permeability) if this did not cause the decisive difference to be lost: mutual interpretation. The fact that two events are in a tension-relationship to each other is presupposed by their distinguishability, their difference. It is these differences that prevent coalescence. Of course, if they do not, the structures are not susceptible.

Susceptibility is a collective term for musical actions with freedom of performance (on the concert platform or in the studio; in the latter, various tapes can be synchronized to form perpetually new versions). Performance freedoms result in variants, and we should not speak of susceptibility until mutual articulation occurs in the majority of the variants. Here a complexity occurs which can barely still be defined quantitatively. The complexity lies more in the fact that a first structure possessing its own quantitative complexity is in a tension-relationship to a second one which also has its own quantitative complexity. The tension-relationship due to susceptibility endows the result of the superposition with an additional formal complexity. It can especially be recognized when the susceptible structures are also presented singly.

[1965]