AFTER THE REVOLUTIONS OF GESTALT AND ACTION CONTROL THEORIES: IS THERE A PSYCHOPHYSICS OF TASK-RELATED STRUCTURAL REPRESENTATIONS?
A DISCUSSION BASED UPON EVIDENCE FROM VISUAL CATEGORIZATION.

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ABSTRACT
A reanalysis of claims of Gestalt psychology reveals that the actual core of its theoretical program is a language-like representational system for perception. The effectiveness of this system resides in its generative power based upon recursive code construction and upon the property that perception expands in time and structure beyond momentary stimulus dependency into memory. Representational issues arising from this view are complex analogues of by now classical psychophysical representation problems. In an experimental section, problems of the joint action of object-related and intentional, demand-related constraints in memory are discussed. Evidence from tasks of structural recognition indicates that demand-related constraints define the relevant sets of traces within which object-related coding proceeds. To portray dynamic aspects of this double determination, findings from experiments are reviewed in which systematic distortions were applied to transformationally generated material. Results suggest the existence of powerful operations of structural extrapolation in perceptual memory.

For psychophysicists it is a commonplace that judgmental performance simultaneously depends on quantitative and qualitative stimulus aspects, and on task demands. With regard to stimulus determinants, already Fechner (1860) was considering, beside intensity and modality, compositional factors such as spatial and temporal stimulus contexts. As for task-related factors, the influence of scale instructions on judgment has, among others, relatively early been taken into consideration (see Stevens, 1975). Scaling, discrimination, detection and recognition situations (cf. Luce, Bush, & Galanter, 1963) have by now become classical examples of different specific modes of processing. In the course of time, the understanding of the two-sided determination has considerably expanded. On the stimulus side it now includes sensory context effects, situational distinctions such as the distinction between lightness of surface colors and brightness of illumination and, last but not least, it also embraces configural dimensions such as figural goodness. The same holds for intentional task demands. Among the expansions taken into consideration, tasks of cognitive information integration appear of particular interest (cf. Anderson, 1998), since their analysis includes combinatorial inner, "psychological", rules of memory-based valuation and merging. Finally, considerable progress has been made in developing process models of task-dependent psychophysical decision making (cf. Link, 1992).

From this brief summary it is only fair to say that psychophysics by studying stimulus- and task-related determinants of judgment made a great step forward from a psychophysical-law-concentrated discipline to an "exact science of body-mind relations" as Fechner envisaged it. Signs of progress should, however, not blind us for weaknesses and deficiencies. Among the apparent shortcomings, one major point is that stimulus-related and intentionally enforced organizational factors have rarely been studied in their joint action. Also, no
theoretical view has emerged that would have allowed us to understand their interplay on the basis of general principles and mechanisms of cognition. These are, of course, no failures of psychophysics as such. Modern psychology and cognitive science as a whole have failed to develop an integrative framework. In fact, since the first decades of the last century and the conceptual revolution of early Gestalt psychology followed by the action-centered Piagetian approach and its Russian derivatives, issues of "autonomous" perceptual organization and of perceptual-cognitive organization as servicing action planning and control have been dealt with quite apart from each other or have even been considered as deriving from mutually excluding conceptions.

In this contribution, I am going to suggest that a reconciliation is not only possible, but is imperative for answering fundamental open questions of cognitive theory. I will approach this goal from two sides: First, from that of a sketchy outline of theoretical problems of Gestalt psychology reconsidering the state of affairs, and, second, by way of a reanalysis of fairly simple and clear-cut experimental findings in visual categorization. The hypothesis on which both discussions converge is the existence of a common level of memory representation on which structured traces of object information as well as equivalents of intentional constraints project.

The Gestalt concept: Basic claims revisited

A discussion reconsidering stimulus-based organization in perception and cognition cannot do without a brief glimpse at Gestalt psychology: There is no doubt that the conceptual innovations invented by the Gestalt movement have left lasting traces in psychological thinking and that experimental inquiry initiated by it has led to important discoveries (see Klix, 2001). For the relevance of its topics today it is certainly indicative that themes of Gestalt perception have become one of the most favored subjects of modern neurosciences and of related psychological research (see Müller et al., 2001).

Unfortunately, it is also true that a restatement of Gestalt concepts cannot do without noting the misfortune of Gestalt psychology in that it often was misunderstood in its basic claims. One of these misunderstandings roots in popular slogans through which it used to be propagated. Thus it became famous for its "Laws of Gestalt" in connection with the notion of Gestalts as wholes "that are more than their parts." Due to this definition, a list of stimulus factors influencing the perceived grouping of objects was put into the center whereas the concept of Gestalt itself was reduced to the non-additive character of wholes appearing as a somewhat mysterious and ultimately superfluous appendix. This, however, turns truth upside-down. To be sure, Gestalt psychology, like any other modern approach toward perception, understood the perceptual outcomes as reflections of real-world situations in terms of objects, their states and interrelations (Wertheimer, 1923). The specificity of the Gestalt claims, however, consists in the form of statements about properties of these reflections which are being considered apart from their correspondences in the real world, not even requiring that such correspondences necessarily exist. Relative to inner representations of structured entities, this is a turn similar to that invoked by the introduction of internal metrics in psychophysics. In this property, constructs of Gestalt not only account for contents of perception for which there are unique correspondences in reality, but potentially also for purely internally generated phenomena such as cognitive contours or even hallucinations. Specifically, Gestalts have been characterized by an expansion of what von Ehrenfels (1890) had called Gestalt qualities. There is nothing mysterious about these "qualities." The claim is that for statements on percepts global relations like "belonging to the same unit", "being part of", or "being caused by" do have the same "real" status of perceptual attributes as any other "classical" attributes, say, seen color or lightness of a sheet of paper or the perceived inclination of a bar. This notion of Gestalt qualities is not restricted to universal relations of this type. More specific perceptual relations such as those between points seen as forming circles or straight lines represent Gestalt qualities as well.
Perhaps, the greatest step done in further explicating the Gestalt view by elaborating upon von Ehrenfels’ concept is certainly that Gestalt qualities have come to be understood as in principle open to recursive combination and nesting. Departing from simple demonstrations such as the hierarchy in a percept like “a seen triangle of squares of circles”, this innovation goes in its consequences far beyond a descriptive list of percepts: In contrast to even modern concepts of structure drawing upon ecological constraints, this view conceptually furnishes perception with the potential “supercapacity” of a language which not only is capable of encoding objects or events, never seen or heard of before, but also gives perception a guiding role in the construction of artifacts which nature is incapable of inventing.

The “true” laws of Gestalt psychology are thus rules of an assumed quasi-language. It is this language-like structure to which the invention of discrete constituents is crucial and which necessitates and enforces their introduction, and not the phenomenal appearance of percepts as it may have been intimated by some representatives of Gestalt schools. Similar to the introduction of metrical relations in a multi-dimensional manifold representing subjective space, the generative representation of structured objects requires definition of proximities. Such a language-like system with its capacity for generating a practically unlimited number of possible structural expressions requires, in addition, tools for comparative valuation of equivalent expressions. To account for the latter, Gestalt psychology introduced a valuation dimension, in German termed "praegnung", for which English equivalents are goodness, self-consistency or, most to the point, degree of singularity (Goldmeier, 1982).

To put it somewhat more generally, the core of Gestalt psychology is the scientific goal of constructing such a system in conformity with known facts on perception of possible objects, their states, mutual relations, changes and their transformations into one another. If this is an adequate idea about perception, there follow important consequences for perceptual processing. Analogous to the absence of a "principle of induction" for reasoning according to modern epistemology (cf. Popper, 1989), i.e. of a general rule for attaining a solution to every empirical problem by induction, there should be no feed-forward mechanism of processing which in every case for any given stimulus configuration could attain an adequate perceptual code as the corresponding "solution". This is why rules for upward assignment of perceptual grouping as those of the so-called "Laws of Gestalt" - however important they may be for identifying the actual implementation of structural processing - cannot solve the problem of Gestalt perception in its capacity as a universal code. In contrast, and again paralleled by an epistemological postulate, namely that of deductive confirmation and rejection, confirmation or rejection of a percept-"option" should in every case be possible by top-down comparison with evidence from the sensory input. This implies that certain equivalents of outputs of lower-stage processes can be retrieved from the final perceptual output.

In a more complete dynamic version, the picture of perception emerging from these premises is that of an inner model of reality that, once being put into existence, is continuously updated in accordance with inner norms of best structuring and outer norms of input congruence (see Geissler, 1983, 1991; for discussion). In this context, initiation of a novel percept must be imagined as a process involving strong bottom-up-top-down interplay as has indeed been demonstrated by most advanced neural and non-linear functional modeling (e.g. Grossberg, 2001; cf. also Grossberg, 1980; Kompass & Elliott, this volume).

**SIT: A calculus for structural description**

Ultimately, the concept of Gestalt psychology as outlined so far represents a theoretical program, rather than a proper theory as the frequently employed term "Gestalt Theory." may suggest. Therefore, the future fate of the Gestalt approach will strongly depend upon further successful steps of conceptual completion and experimental corroboration.
According to my rather sketchy outline, a crucial demand should be the development of a suitable calculus for the formal representation of perceptual structure. From the very nature of this aim, its attainment can in principle not be expected from any processing theory of grouping, be it purely functionally motivated or be it inclusive of assumptions on neural substrates. The simple reason is that such approaches cannot go much beyond the representational assumptions invested beforehand (cf. also van Leeuwen, 1989; for a discussion). Rather, the goal envisaged involves the explicit solution of representational problems that are discrete analogues of representational issues in psychophysical measurement and scaling. A particular intriguing problem in the discrete case is implied by the fact that the internal manifolds on which relational structures are to be defined are largely unknown and cannot simply be anchored in physical manifolds as, for instance, the points of a subjective space in points of the corresponding physical space. Thus, reasonable suggestions have to be based upon careful interactive analysis of empirical phenomena.

How should a formal calculus for the representation of perceptual structure look like? The representatives of Gestalt psychology Wertheimer, Köhler and Koffka did not succeed in precisely formulating the goal of a language-like calculus. However, elements of such a calculus emerged step by step within several decades of related developments. From those who can be considered as constituting the next waves of the Gestalt movement came valuable experimental and theoretical foundations, among others, from Attneave, Buffart, Garner, Goldmeier, Hochberg, Klix, van Leeuwen, Leeuwenberg, van Lier, Metzger, Michotte, Mens, Palmer, Rausch, Restle, Rock, and Simon.

The only approach that has succeeded in developing a formal calculus of the appropriate recursive properties, equipped with considerable generative power, is that of the Structural Information Theory (SIT) as suggested by Leeuwenberg (1969) and Buffart & Leeuwenberg (1983), and its more recent expansions (cf. also Leeuwenberg, 2001). The essence of SIT is a description of perceptual structures by serial string codes consisting of nested expressions that can be generated from strings of elements, referred to as primitive codes, by explicating identities. Operators express relations such as repetition or iteration (n \( \times \) denoting n-fold repetition), symmetry S, and sequential alteration. Codes include repetitions by numbers of iterations. Although the denotations of elements have to be defined intuitively and ad hoc, in many cases of interest the choice is straightforward and intuitively convincing and can post hoc be supported by experimental evidence.

To give an idea of how SIT works, let the letter sequence abbaabba represent a primitive code. Possible codes are then: (A) \( 2 \times (abba) \); (B) S(ab)S(ab); (C) \( 2 \times S(ab) \). Here (C) can be conceived as a transformation of (B) explicating the identity (repetition) of the two partial expressions S(ab). No further transformation of C by operators is possible: It represents what is termed an end-code. From among the possible expressions it also contains the smallest number of elements left as arguments, which is referred to as a minimum code.

Formal expressions like these permit the definition of measures such as of goodness. Early in the development of the approach, the number of remaining elements was introduced as "information load." This measure is suitable for comparison of different end codes of one and the same primitive code and has proved a good predictor of perceptual ambiguities. It does not seem to be suited for a comparison of configurations which, although built of elements of the same denotation, differ in their "degree of structuring." Thus, the expressions \( 2 \times S(ab) \) and \( 2 \times (ab) \) do have the same information load, but the corresponding percepts may not be of equal complexity.

Expressions like (A), (B) and (C) correspond to different structural "interpretations" of identical stimuli that exclude one another. This can also be the case for different end codes to a given primitive code. For example, abbaab may be coded as \( 2 \times (a \ 2 \times (b)) \) or as \( S(ab) \ 2 \times (b) \).

As one readily realizes, a corresponding sequence of one white circle and two black circles can indeed either be seen as a repetition of a chunk of this content or as a symmetric configuration of two black circles flanked by white circles which is followed by a block of two black circles. In
agreement with the different information loads, the latter interpretation is more difficult to attain and arises less frequently in spontaneous grouping, which exemplifies a possible way for quantifying the Gestalt law of "absorption without a remainder" (see Metzger, 1963).

I can not dwell upon details of empirical validity here. Suffice it to say that the SIT approach has been shown to be empirically superior to other attempts in several respects (cf. Restle, 1982, for an evaluation). For the present purpose a short discussion of imperfections, from which directions of necessary developments can be anticipated, seems to be more important.

On the most general level, a major drawback of the formalism can be seen in the lack of tools for addressing topological relations such as "being inside" a closed contour. However, the need for additional descriptive tools is already evident within the realm of structures for which SIT was originally designed. Most literal applications of SIT are perhaps those to musical structures, because in this domain temporal sequences of tones uniquely correspond to sequences of primitive-code elements. A similar case is exemplified by sequences of figures. SIT was successfully employed in the construction and valuation of figural-test items (see Guthke et al., 1991). Even in this case, it is a tacit assumption that the particular arrangement in the two-dimensional space induces a unique sequential order of coding. The approach was also of considerable success in figural contour coding which, however, requires an ad-hoc sequentialization of contour elements with an arbitrary beginning. Arbitrariness can be avoided by the more natural assumption that structural interpretation generally operates upon other, non-structural representations. In this revised conceptualization, artificial serialization can be replaced by pointer-attaching of code constituents to segments of non-structural representations. In general, to describe coexisting, not mutually connected, contours or nested figural structures as postulated by Chen (2001), an introduction of topological descriptions will be necessary.

A further formal defect of SIT can be seen in the fact that it does not provide a natural way for the expression of transformational relationships as exemplified by the Gestalt property of transposition invariance (Ehrenfels, 1892). However, as various proposals of corresponding descriptive systems (e.g. Garner, 1974; Restle, 1979; Leyton, 1992; see also Schmidt & Ackermann, 1990) have demonstrated, transformations, often forming discrete or continuous groups in the mathematical sense, are essential to grasp important types of perceptual-cognitive structure. Part of the problem is the inability of SIT to naturally account for metrical properties of percepts and their influence upon perceptual valuation. In actual perception, objects appear to be coded in relation to normal positions and normal sizes (see Palmer, 1992). Deformed objects seem to be represented by the code of an idealizing object plus that of the deviation from it. Depending on the variation of continuous attributes there are perceptual structures of highly singular, of non-singular, and of weakly ordered codes (Goldmeier, 1982; see also Metzger, 1963). Partly, SIT might account for these phenomena by introducing fuzzy categorizations of primitive code elements. However, a full account is impossible without reference to metrical information.

Thus, as these remarks indicate, for those who are interested in perception in its structural complexity an enormous amount of fascinating work is waiting.

**A major difficulty and a tentative resolution**

From the above outline, it is sufficiently clear that a theoretical construction of this type is bound to be misconceived or prematurely rejected, particularly in a scientific community in which empirist views are so dominating. Certainly, the approach does not present itself in terms of a falsifiable theory, and thereby precludes straightforward operationalization and testing. But there are even deeper conceptual difficulties making theorizing full of pitfalls. A puzzling problem at the very basis of the approach is the seeming tautological character of Gestalt qualities. It appears obvious that the only way to demonstrate the existence of a certain quality and to delineate its invariance properties is via the systematic variation of stimulus conditions, i.e. a strategy in accordance with the popular "Law-of-Gestalt" perspective. The puzzling thing is that to each Gestalt-quality
problem there exists indeed a corresponding Law-of-Gestalt problem in the common understanding, although this correspondence can often be a many-to-one or a one-to-many map. The necessity of mechanisms supporting Gestalt formation goes without any doubt. The example of face recognition relying on the activity of a large brain area illustrates the importance even of very specialized devices. How then could Gestalt qualities be demonstrated as entities in their own right? And how may they be investigated and established without relying upon the way of stimulus variation leading to statements of the out-side-in type of the "Laws of Gestalt"?

Here is a really crucial point: Actually, the problem would not exist in this form, if perception were completely bound to stimulus presence. But perception is not just interpolating and anticipating in space and time. As an electromagnetic wave separates from the flow of current that produced it, a percept is accompanied by an activity surviving it as its memory trace. Although there is not yet much exact knowledge about the properties of perceptual memory traces, there are pieces of evidence sufficient to indicate that these residuals differ as a function of contextual conditions during encoding, including attentional set and time available for encoding, and depend upon semantic and episodic relations in a more remote context as well as upon time elapsed after encoding. Changes with time may also imply differences in abstraction. The Gestaltist Hedwig von Restorff (1933) was the first to hypothesize that memory traces are subject to the same fundamental laws of Gestalt as are the actual percepts. Unlike stimulus-bound percepts, however, perceptual memory traces are subject to spontaneous change not only by mere decay, which can be exploited as a tool for studying the representational system.

In the study of perceptual memory traces and their dynamics recognition and recall paradigms are greatly favored. In the present context, studies of Goldmeier (1941, 1982) are particularly relevant. By operationalizing singularity as resistance to change he succeeded in showing that theoretically singular structures are most resistant to change. Near-singular structures change in the direction of singularities while non-singular structures undergo random changes. Goldmeier's account for this reads like an anticipation of synergistic models (cf. e.g. Haken, 1983). It attributes change to small internal perturbations that randomly alter quantitative, and indeed also qualitative, trace attributes. Traces are characterized as points on an energetic relief in which singularities represent troughs. Perturbations acting toward lower levels lead to greater energetic changes than those acting in the counterdirection. Therefore, the deeper the trough the smaller the probability to leave it, i.e. the higher the stability of a singular state. Near-singular structures correspond to states in the vicinity of a trough. Consequently, they will with high probability transform into singularities. Non-singular structures, on the other hand, correspond to flat regions of a relief in which they will be moving forth and back, in a kind of random work.

The action of intentional task-constraints in perception-based memory coding

Let me now turn to the issue of task-dependence in the light of selected experimental findings. From a representational point of view, the main point is that memory residuals of perception cannot, as a rule, be traces of isolated objects or events. Rather, they are retained as parts of perceptual categories ("concepts"), constituents of scenes, connected sequences of events etc., often in association with actions. In everyday-life situations, these contextual conditions are highly overdetermined. Memory structuring, its temporal dynamics and the retrieval of information are therefore complexly determined and highly idiosyncratic. In the recognition of a single object and even more so in recall, all available cues making up its distinctiveness in memory will normally be employed. For this reason, to study the memory dynamics of single visual percepts, small sets of sufficiently distinctive figures were employed, at the same time minimizing activity of object-external factors (Goldmeier, 1982). For the present goal of exploring joint action of stimulus and task constraints, for a start, it seems best to choose conditions in which individual-percept-related trace dynamics is minimized and the main effects to be expected are in a most clear-cut manner related to potential object-set structures and task constraints. This was accomplished by using
materials generated from sets of geometrical primary patterns through combination or transformation and employing multi-categorical naming and verification as task demands.

In this section, I will draw upon work carried out jointly with former students and colleagues, in particular with Martina Puffe. For complementary recent developments the reader is referred to joint work with Th. Lachmann (cf. Lachmann, this volume; also Geissler, 2001).

As a first group of examples I take up recognition situations in which the joint action of stimulus and task-related factors is revealed only by its (quasi-) stationary results. Figure 1 shows the type of geometrical patterns employed in the experiments. For sets of items like these, routines establishing a correspondence map between parts of the patterns in the format of feature dimensions are essential to memory encoding. In the particular case, these dimensions may be termed "outline contour", "in-set contour" and "filling-in structure."

To describe structural properties of sets of objects formed from this material a tentative expansion of the Structural Information Theory, SIT, was introduced. A simple example is an operator explicating the identity of features on a certain dimension. Let, for example, \((a_1, b_1, c_2), (a_2, b_2, c_1), (a_3, b_1, c_3)\) be descriptions of items by features on configural dimensions A, B, C. Then the agreement in \(b_1\) can be accommodated by an expression like \((\bullet, b_1, \bullet) \times [(a_1, \bullet, c_2), (a_2, \bullet, c_1), (a_3, \bullet, c_3)]\) meaning that the empty argument in the three codes is to be substituted by \(b_1\). Since the letters uniquely indicate dimensions, a simpler possible convention reads \(b_1 \times [(a_1, c_2), (a_2, c_1), (a_3, c_3)] = (a_1, b_1, c_2), (a_2, b_1, c_1), (a_3, b_1, c_3).\)

To begin with, let us consider evidence from an item recognition paradigm sensu Sternberg (1966). Figure 2 displays curvilinear RT trends obtained for negative decisions and memory sets of sizes \(s = 1, 2, 3\), exhibiting no feature redundancy. Dashed lines represent predictions from one out of three near-equivalent descriptive two-stage models. In this model, the occurrence of the first stage apparently reflects the need to translate test items in a serial top-down procedure into a format allowing comparison with stored memory set items.

In further series, feature redundancy was varied. In Figure 3, mean RTs are displayed for the example of \(s = 2\) and two redundant features (\(R = 2\)) of the memory set. On the left-hand side RTs are plotted against numbers of features assuming that all features of items are to be tested separately. On the right-hand side these numbers are reduced in accordance with the assumption that redundant features are tested as if they were represented only once. The latter plot practically coincides with that from the data in the case of no redundancy, indicating that redundant features are indeed represented but once.

Clearly, this result is analogous to argument reduction in the momentary-percept paradigms of SIT. It does not, however, provide information about the joint action of stimulus and task constraints. In order to explore this issue, further experiments were carried out in which for one and the same set of objects task constraints and the structural composition of task-induced object categories were systematically varied.

![Fig. 1. Examples of elements for the construction of patterns used and an example of a pattern.](image-url)
Fig. 2. Mean RTs in negative decisions for set sizes $s = 1, 2, 3$ in an item recognition experiment and predictions (dashed lines) from the two-stage processing model illustrated on the right-hand side. Stage 1 involves self-terminating top-down memory encoding along dimensions, stage 2 self-terminating item-wise checking.

Fig. 3. Mean RTs as plotted against total number of item features (left), and against number of features assuming that redundant features are represented and tested only once (right). Note that the latter plot practically coincides with that for $R = 0$ (dashed line). $r$ denotes redundancy relative to current item, $R$ the total redundancy of memory sets.

Figure 4 provides a sketch of category compositions employed in the three series of one of these experiments by way of the tree structures A, B, and C. In the acquisition phases, names (non-sense syllables) were learned for each category. In the test phase of the series either naming or verification was required. In naming, levels of responding in correspondence to the hierarchy levels of the trees in Figure 4 were cued by specific level names before an item was presented. In verification, category names were presented before item presentation.

To account for this, category labels have been formally attached as constituents to the "primitive codes" of categories with the property that only those features can be moved outside the code expressions marked by a label which are non-distinctive, i.e. in common to all categories on a given level. For example, let $(a_1, b_1, c_1)R_1, (a_2, b_2, c_1)R_2$ be the "primitive codes." Then $(c_1) \times [(a_1, b_1)R_1, (a_2, b_2)R_2]$ is an admissible transform. Processing is assumed to be self-terminating on the
feature level and exhaustive on the subcategory (constituent) level. In naming, it is assumed that after a match with the category code has been found the response corresponding to the category label is elicited and that feature checking after category mismatch jumps to the next code in the sequence of category codes. In applying this rationale no memory encoding stage could be separated in analogy to item recognition, a plausible reason being that memory encoding of test items on each hierarchy level claims a nearly constant portion of total processing time.

Fig. 4. Trees A, B, and C schematically representing the category structures of the corresponding series. In A on the top, for categories of more than one object only the common features are indicated. For B and C the corresponding places are filled by black circles as the occurrence of common features in sub-categories is subject to special conditions.

Fig. 5. Data (solid) and predictions (dashed) for series A, B and C in naming (triangles) and verification (circles). t, m, b denote top, medium and bottom levels of cueing, respectively. For further explanations see text.
In Figure 5, mean RTs for series A, B, and C in naming and verification are presented together with the descriptive-model predictions (dashed lines) resulting from simultaneous fit of naming and verification data. As can be seen, in each case predictions agree with the empirical trend structure including subtle differences and even trend reversals as are found for verification between A and C. The model interpretation is strongly supported by a solid agreement of operation time estimates across the three tasks which are 356, 350 and 330.5 msec, respectively. Note that the estimates refer to an arbitrarily fixed category-scanning sequence and averaged data. If relying on a technique that accounts for individual differences, they have to be corrected to an absolute value of about 270 msec (cf. Geissler, 2001).

These results corroborate that feature identities within and between memory codes of task-defined categories are explicated in accordance with the assumed rules of coding. It is important to note that this type of task-related memory coding generally implies a considerably higher number of decision steps than would have to be expected for an optimal decision procedure ignoring representational constraints. For example, on the bottom level in naming, on the average 8.5 operations are required as compared to the absolute minimum of 3 operations obtained when presuming a dichotomization strategy. This phenomenon, which emerges as a necessary consequence of representationally guided processing, has been referred to as Seeming Redundancy (Geissler, 1984).

With estimated operation times under the investigated conditions of around 300 msec, operations are fairly slow. Thus the concern arose that the identified serial strategies might be characteristic to states of low practice. To explore this issue - employing a somewhat simplified version of the series-A situation which included only two cueing levels - subjects were trained over six sessions. A change toward optimization in terms of number of decision steps would have implied a decrease in RT spread between cueing levels in naming relative to that in verification. However, although estimated operation times decreased by nearly 50%, not the slightest decrease in this ratio was found (see also Geissler, 2001). This gives sound reason to assume that also for much higher degrees of training and further concomitant strong reductions of RTs no principal change will arise. One is, therefore, tempted to speculate that identical rules of representationally guided processing are maintained to preserve the universality of cognitive procedures, including recombination of routines of controlled and automatic processing.

**Coding of distortions in task-related memory codes**

The above-quoted experiments do not permit statements about memory coding of quasi-continuous perceptual parameters. Goldmeier's experiments, employing distortions leading to changes of continuous parameters, were directed toward the temporal dynamics of memory traces of single objects. This excludes identification of the joint action of stimulus and task constraints with respect to sets of objects. To explore the issue, a series of naming experiments using angular patterns was carried out (cf. Geissler, 2001; also Geissler, 1980). The bold-face patterns at the top left of Figure 6 (numbered 0), schematically depict the standard set of 16 patterns employed This set consists of two structurally distinct subsets: a set of angular patterns with orthogonal legs (set I) and a set of patterns including an angle of 45 degrees (set II). In their turn they fall apart into two closely
Fig. 6. The standard set of 16 patterns (in bold) and five distorted versions of it used in naming experiments. The digits indicate how many times the original patterns are subjected to vertical shrinking by a factor of 2/3 defined as "degree of distortion" (DD). Note that DD reflects physical distortion on a logarithmic scale.

Interrelated subsets, set I into 4 patterns that are symmetric with respect to the main spatial axes and 4 pattern with axis-symmetric legs, set II into 8 patterns each with one horizontal leg and 8 patterns with one vertical leg each.

The patterns below and on the right side of Figure 6 (numbered 1 through 5) represent distorted versions of the standard set which are obtained through repeated vertical shrinking by a factor of 2/3. Note that the attached numbers represent the exponents of the geometrical sequence of distortions and, thus, represent physical distortion on a logarithmic scale. In the following, therefore, these numbers will be referred to as "degrees of distortion" (DDs).

In the experiments, subjects had to respond to patterns of the standard set and to distorted versions of them with specific learned names (nonsense syllables). Hypothetical formal descriptions of the underlying representational basis can be developed in analogy to SIT. The patterns of the standard set are represented by repeated application of transformations forming discrete groups (in the mathematical sense) to pattern prototypes. Correspondingly, the distortions can be conceived as elements of a transformation group whose operations are not commutable with the standard-set generating groups. Precisely in analogy to non-distinctive features in feature generated sets in end code representations, the action of distortions can formally be separated from the remainder of the category descriptions. Unlike the processing of non-distinctive features in the case of feature codes, however, processing of code constituents corresponding to "irrelevant" transformations can neither be exempted from processing nor processed in parallel to those deriving from "relevant" transformations. As a consequence, they should systematically depend upon DD. Fortunately, however, this provides additional tools for portraying crucial properties of the representational structures.

To avoid an introduction of a somewhat complicated formalism of transformational relations here, I will confine myself to essentials which will be explained through illustrating experimental findings.

Basic differences between the processing of structure in perception in the narrower sense and that of processing of object and task-related memory structures are most easily realized from findings of an experiment in which undistorted and distorted patterns were balanced throughout acquisition and testing.

In Figure 7, on the left-hand side mean RTs from 6 sequential blocks are plotted as functions of DD. The empirical functions exhibit u-shaped courses that do not significantly change in the sequence of blocks. Contrary to any simple Gestalt claim, this implies that processing is quickest in the middle of the distortion range rather than at DD0, which corresponds to highest goodness or singularity of each of the individual pattern elements. This statement holds both on average and for the pattern-subgroup means shown on the right-hand side. There is a small RT advantage to be noted of the DDs 0 - 2 on the side of the lower distortions over their corresponding DDs 3 - 5 on the side of the higher distortions causing a small deviation of the functions from ideal symmetry, which can be attributed to quicker "sensory" processing of patterns being closer to
singularity. In fact, between the singular, highly symmetric exemplars and the most distorted ones (=DD5) this difference is of the order of 10 to 20 milliseconds as compared to a lead of 150 to 250 msec of the center of the range of distortion. There is certainly no better demonstration of the dominating top-down character of memory-related processing!

Another relevant finding consists in a difference in mean processing time between subsets I and II of more than 400 msec which nearly equals that found in experiments with undistorted patterns. The less singular patterns of subset II are processed more slowly. However, this effect cannot be attributed to properties of the individual patterns concerned. Rather, it derives mainly from search of a more extended memory structure corresponding to an equivalence set embracing 8 patterns (under the transformations from the dihedral group D4 in the plane), whereas for subset I this search set contains only 4 elements.

Experiments with distorted patterns are well-suited for studies of the temporal dynamics of task-related memory structures and will in this manner provide deeper insight into the nature of these representations. Figure 8 provides a comparison of results from the test series of two experiments employing different regimes of temporal structuring. In both experiments, only the standard set of patterns was presented during acquisition. In the experiment corresponding to the left side of Figure 8, patterns were presented during testing in (quasi-) random order with equal probabilities in DDs 0 - 5. The temporal changes visible for the 6 blocks of the first experiment can be interpreted as a smooth transition from a processing regime referring to a representation based upon the standard set to one referring to the full set of distorted and undistorted patterns. In the second experiment pattern presentation.

Fig. 7. Left: RTs for six sequential testing blocks and overall means plotted against DD. Right: RT means for subset I and subset II. Note the small deviation of the mean functions from ideal symmetry indicating a slightly quicker processing of patterns which are closer to the symmetries of the standard set.
was block-wise alternating between DDs 0 - 2 and DDs 3 - 5. The most striking feature of the outcome are two u-shaped curve segments in the initial four blocks which, to be consistent with the former interpretations, is to be attributed to a representation of two partial ranges of distortion. The fact that a representation of the standard-set related response map remains to be active is indicated by an overall left-right increase corresponding to that found in the former experiment. During the final blocks of the test phase the shape of the function closely approaches that of the temporally unstructured condition.

With respect to stimulus-related structuring per se, both rows of results suggest that naming of the "singular" standard-set patterns refers to a discrete structural representation, while the introduction of distorting transformations corresponding to the continuous physical parameter of compression leads to an embedding of the entire set of undistorted and distorted patterns into a range-like ordering of representations. In this, the impact of task constraints is reflected in the suppression of a subrange structure which has no correspondence in the task-related partitioning. It may be noted here that simpler representations by several simultaneously active referents cannot be reconciled with the pattern of results as a whole.

From the formal transformational structure follows that the transformations corresponding to distortions should act upon the equivalence sets within the standard set. Because of the near-symmetric shape of the empirical functions this belongingness cannot be demonstrated by data from the experiments quoted. To demonstrate this form of "group coding", an experiment employing only group-I patterns was carried out. Subjects were trained with the standard set. In the test phase, for the pattern with the orientation of a V presentation frequency was locally increased 15 times in one particular DD, namely DD 4. Figure 9 shows data from the second half of the test phase. The minimum of RT as a function of DD is shifted toward DD4 not only for the pattern directly concerned by an increase in local frequency, but for all members of the equivalence set of patterns. Beyond this, the means for the patterns with axis-parallel legs - depicted by a dashed line - show nearly exactly the reverse trend of the patterns with axis-symmetric legs.

Explanation of these results by means of processing models requires the assumption of distance dependent decisions, with distances including two contributions of opposed signs. From a representational point of view which is on focus in this contribution both results strongly emphasize a group-coding explanation, here by common coding of a dimension of vertical shrinking. This is in sharp contrast to any explanation based upon single-percept properties in the Gestalt tradition as well as in modern early-feature-analytic views, because phenomenal appearance and "sensory features" of individual patterns may vary very differently with distortion. For example, patterns from the set of axis-symmetric patterns may become more acute or more obtuse angled, depending on spatial orientation (cf. Figure 6).

There is a final and, in my view, most interesting observation resulting from all of the reported series: Massive signs of adaptive structure formation arise already at a point of time when each individual subject has been exposed only to a part of the entire space of $16 \times 6 = 96$ elements. This suggests the existence of fast processes of structure formation in memory, involving an unprecedented degree of implicit extrapolation and abstraction, which intentional processing can benefit from. With
this aspect, the present discussion is just touching upon issues of dynamic structure formation which represent a field of research in its own right (cf. van Leeuwen, & Raffone, 2001).

**References**


