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Cultural Constraints on Cognitive Representation

Starting from Kant's notion of schemata as being rules of synthesis, this paper attempts to develop a unified characterization of innate and culturally mediated schemata. The core concept for this approach is the translation or transformation from one code to another or to some others, which preserve a set of invariants. It is argued that the alleged mechanism of transformation makes possible the development of schemata for complex externally mediated tasks, which are at variance with innate schemata, examples for such tasks are dancing tango or understanding perspective drawings.

Such a notion of schema bears a strong structural similarity to algebraic groups with certain invariant-preserving transformations. This concept can bind together Helmholtz' 'unconscious conclusions' and Hering's explanation of perceptual constancies. It is suggested to apply heuristically the Gestalt principles and laws of perception as invariant-preserving transformations on the content of schemata. By means of an analysis of different tasks the heuristic value of this approach is demonstrated.

Exactly 200 years ago Kant turned around the argument of Berkeley and other Empiricists concerning the truth of abstract ideas, by stating that the a-priory existence of certain rules makes possible the perception of particular instances as such and not vice versa.1) The juxtaposition of a-prioristic and Empiricist views of perception and representation of knowledge was modified further by Helmholtz, who demonstrated that the geometry of the perceptual space is not Euclidean under certain conditions. Therefore the imposed rules are not a-priori but depend on the perceptual task and the cultural and/or phylogenetic development. An even more radical modification is stated in the Sapir-Whorf hypothesis, which pointed out the important intermediate role of language. Despite its apparent relevance for models of human knowledge representation the very role of cultural knowledge in the development and usage of individual knowledge has remained largely undefined.

The comparison of the well-known Necker cube in figure 1, and of a slightly varied form in figure 2 raises immediatly the question, why figure 2 appears to be more 'right'.

Figures 1 & 2

Comparison of two ways to draw a cube

Figure 1

parallel edges of the drawn object are mapped into parallel lines of the same length as in the drawn object

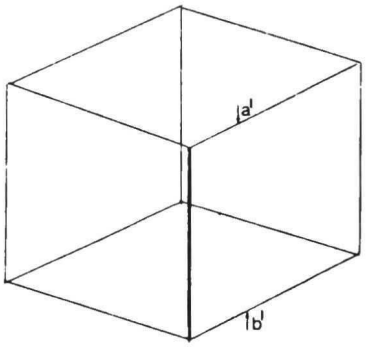
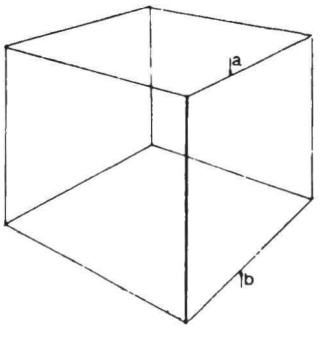


Figure 2

parallel edges are drawn as lines with the same vanishing point and the length of the lines depends on the perspective foreshortening



1) Nietzsche summarized the content of Kant's Critique of Pure Reason in a witticism: "The content is quite simple; Kant showed that the ordinary man is right about perception and that the scientists are wrong. Unfortunately this content is hidden in language, which can only be understood by scientists."

The answer that figure 2 is exactly drawn as we perceive a cube, is not quite convincing; for it provokes the further question, why the art of perspective drawing is a comparatively recent development (about 500 years old), why most people are not able to do it without instruction, and why in cultures not influenced by Western Renaissance art or Chinese art one does not find geometrical perspective. Even if these broader cultural considerations are not taken into account, there remains the puzzling question, why in the context of the cube drawings in figures 1 and 2 the slanted lines a and b in 2 are easily seen as the parallel edges of the right side of the cube, whereas the really parallel lines a' and b' in figure 1 do not elicit this impression as easily.

Various investigations have corroborated the existence of perceptual regularities like the ones of Gestalt psychology; one striking example is the grouping due to the 'same fate' (e. g., parallel curves). If it is assumed that grouping parallel lines is an innate rule for information processing --and it is difficult to see how these lines coulf give rise to the impression of a cube otherwise1) --then the equating of 'straight lines meeting in the same vanishing point' with 'parallel lines on a slanted plane' points out, how cultural constraints can influence the rules, which govern human information processing.

This notion of rules, which allow the perception of spatial forms as such, is due to Kant in his argument against Berkeley's denial of truth in geometry (Critique of Pure Reason). Even if Kant's insisting on these rules as a-priori truths is dismissed nowadays, his development of a schema theory gave rise to conceptualizations in psychology, which opened ways out of the paradoxical situations, into which overconfident reductionism had led psychology. In this context it suffices to reconstruct Kant's idea and some of its applications and further developments in order to point out, what a schema theoretic approach to the introductory problem could look like.

Berkeley had stated that there can be no truth in geometry since theorems of geometry pertain to infinite classes of objects in space (e. g., triangles). According to the empiristic criterion of truth as based on perception (esse est percipi), there cannot exist truth for infinite collections, because that would necessitate the storage of an infinite number of sense impressions (images) for each such class in the human brain. Kant (in 'Critique of Pure Reason') inverts Berkeley's argument by starting from the concept of rules giving rise to an infinite number of images, which can be paired with figures in space: "The schema of the triangle can exist nowhere but in thought and signifies a rule of synthesis of the imagination in respect to its figures in space."1) The connection between the figures in space and their representation in the human brain is made possible through active perception: "... imagination is a necessary ingredient of perception itself." And Kant resolves Berkeley's paradoxical conclusion about the storage of infinitely many images for abstract concepts, by coupling the abstract concept with the active device of the schema, which is able to produce all possible examples for a given concept: "These images can be connected with the concept only by means of the schema to which they belong. In themselves they are never completely at one with the concept."

These ideas have had a strong influence on physiologists in the last century and in the beginning of this century: on Helmholtz and Hering in Germany, on Head in England. The transformations of Kant's schema theory by these scientists in turn influenced Gestalt psychology in continental Europe and Bartlett's conceptualization of psychology in England. Especially the application of this theoretical framework by Head and Bartlett has obscured the distinction between the abstract concept, the active schema, and the ad-hoc produced images. This led to such a vague definition of schema, that this label could be used to denote any steps in the chain of information procession, which seemed to be too complex to be analyzed further. Rumelhart (1980) and others have argued that for the concept of schema to play an important part in cognitive psychology, it is necessary to clarify its definition an d to develop mechanisms to test the feasibility of the concept. But even Rumelhart's notion of 'Schemata as Building Blocks of Cognition' organized in a hierarchical way, seems to have certain weaknesses:

- it necessitates the assumption of primitives in order to avoid infinite regress downwards, while lacking self-evident criteria of demarcation between schemata and primitives
- it does not exclude a possible infinite regress upwards; there always is still another schema necessary to control the top most schema

An alternative strategy to define the concept of schema and at the same time to circumvent some of the mentioned pitfalls, can start by going back to Kant's notion of schema as 'a rule of synthesis', which formed the theoretical framework for Helmholtz', Hering's and Gelb's explanations of constancies in human perception. Helmhotz: "... the law of sufficient reason is really nothing more than the

1) There is an infinite number of two and three dimensional forms which are in agreement with the topologies of figure 1 and 2, which by the way are topologically equivalent.

1) italics by the author

'urge' of our intellect to bring all our perceptions under control." Hering: "... objective knowledge and objective judgment are rendered possible by this constancy," and Gelb: "The idea of invariance, which is an epistemological problem of validity of the foremost importance, has one of its roots, and perhaps the most intuitive one in the psychology of perception."

The search for such invariants and for the related classes of transformations formed the research program of Gestalt psychologists, as can be seen in Köhler's summing up the basic ideas of Ehrenfels: "It is characteristic of phenomenal forms that their specific properties remain unchanged, when the absolute data upon which they rest, undergo certain modification." In Gestalt psychology rules have been developed which pin down invariants and their transformations in perception: the 'laws' of grouping, of saliency (Prägnanz), etc. Unfortunately in the generalizations to more complex forms of human behavior much of the original clarity has been lost. Another limitation of the Gestalt approach is its nativistic orientation, which prevented Gestalt psychologists to realize the interaction between these innate rules and external (e. g., social or cultural) knowledge.

Various analyses (e. g., Uttal, Julesz) have shown how the application of simple filters or auto- and cross-correlation techniques are able to detect regularities (e. g., figures) in apparently random patterns; these results are under certain conditions (types of symmetry, parallel curves, straight lines) the same ones, as one gets with human observers. If one takes the underlying rules, which enable the organism to detect forms in random noise or to discriminate between different forms, as the most primitive building blocks of perception, then it is possible to explain the emergence of schemata. These schemata can be defined as unique combinations of the primitive building blocks under constraints of the organism (e.g., channel capacity, coding capacity) and the environment, upon which these schemata are applied.

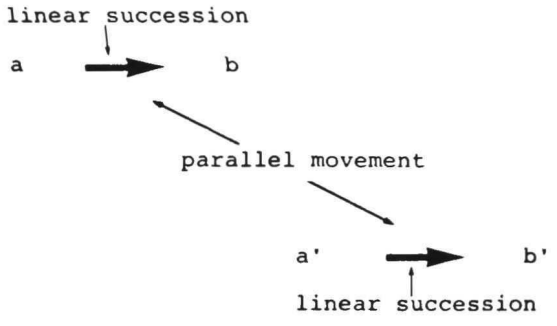
One major objection to this view could be that the invoked rules might be true only for certain modalities; the fact that 'Gestalt-laws' mostly stem from research in visual perception seems to corroborate this critique. What would be the consequence for an assumption of modality specific rules? At first it necessitates further non-analyzable units, which make possible the translation from one sensory code into another, in order to explain highly integrated human activities such as script-writing (integration of kinesthetic, visual and 'symbolic' codes) or dancing, where kinesthetic, vestibular, and acoustic codes influence each other. These activities are not only highly learnable, but they exhibit the mentioned kind of integration from the very beginning (concededly in varying degrees). Furthermore it would be difficult under this assumption to explain synesthetics, the emergence of immediate impressions of similarity between experiences in different modalities (which give rise to self-explaining similes and metaphors) or intermodal rivalry and its resolution. To sum up: The assumption of modality specific rules gives rise to a less parsimonious explanation of inner organismic communication.

This negative argument for modality independent rules can be supported by the demonstration of structurally equivalent rules in different codes: e. g. In grouping perceived objects the rules of linear succession and parallel movements exert strong influence. These very rules are structurally equivalent to the mechanism assumed for the solution of analogical problems by Rumelhart & Abrahamson (1973), as can be seen in figure 3:

If b is linear succession of a, and b' is a linear succession of a', and if the movement from a to b and from a' to b' are parallel, then b' ist the solution of the analogical problem a : b = a' : ?

a, b, a', and b' can stand for verbally stated concepts, for bodily movements, or for acoustical phenomena, and thus can give rise to the resolution of such different tasks as finding the correct verbal expression, as doing the right leg-arm coordination in skiing, or as composing a fugue. It is apparent that in these applications only the set of rules remained invariant, whereas the internal as well as the external constraints changed totally.

Figure 3



perceptual rules underlying analogical problems of type

a : b = a' : ?

On the background of this discussion a schema is a set of primitive rules which are coupled in a unique combination under intra-organismic and extra-organismic constraints for a certain task. In the framework of this task the schema appears as a no-further-analyzable unit and can be considered as a pragmatic primitive. Task hierarchies then imply hierarchies of schema too, thus indicating that the focal point in the perception of the task hierarchy influences, what can be determined as a pragmatic primitive. Form this point of view the function of the schema can be assumed as twofold:

#1 the generation of possible constellations (e. g., strings of symbols, sequences of movements, figures) and their comparison with perceived constellations

#2 the extrapolation of future states of the organism and their comparison with perceived states.

Whereas the former allows identification and classification of information and events, the latter makes self-regulated goal-directed behavior possible. A combination of both functions underlies behavior, which is regulated by external feedback.

The influence of cultural constraints on the functioning of schemata can be observed best in instances, where the rules of the cultural constraints interfere with the rules of an either inborn schema (e. g., upright walking of humans with a characteristic arm-leg coordination) or an individually developed schema (e. g., certain motor patterns which make up the invidual characteristics of script, drawing, or gesticulation). Such an interference is mostly possible, if the existing schema can produce particulars (in Cassirer's sense) in agreement with the cultural constraints in the limiting case but not in the general case. This situation can be clarified by two examples from different domains.

The cultural constraints on a mode of argumentation typical for the Western culture can be found in the rules of syllogistic reasoning. Psychological analyses of this task since Wertheimer have demonstrated, that formally equivalent problems lead to totally different patterns of successes and errors, and that framing, which does not alter the logical structure, influences the probability of success in a highly predictable way. If the rules of perception are taken as primitives for a schema of argumentation, then these rules, especially 'neighborhood', 'succession', 'same fate', and 'parallel curves', can be taken as the underlying cause for Johnson-Laird's figurative effect as well as for the superiority of concrete problems over abstract problems of the same logical structure.

The learning of movements in dancing is another example for the interference of cultural constraints with inborn schemata. Physiological as well as psychological analyses of human motor behavior have demonstrated that its apparent smoothness is due to CNS-controlled 'pre-enervations', which allow a very fast sequence of the same or different movements, e. g. in walking (same), or jumping (different). A necessary precondition of these 'pre-enervations' seems to be, that one movement follows the ather in 'a natural way'. If the perceptual rules are assumed to characterize this 'natural way', then it becomes plausible, why tango seems to be one of the most difficult dances to learn. The initial sequence of steps makes use of the pattern of normal walking. Part of the walking schema is stopping, but in tango instead of a simple stop with subsequent change of direction a kind of oscillation of the body is preseribed, which is only found in this type of dancing. Thus the invariants of tango are incompatible with the schemata of walking as well as of other kinds of dancing. The obvious fact, that this movement can be learned nevertheless, may be made possible by the translation of the rhythmic invariants contained in the melody, into rhythmic patterns of bodily movements. The fact, that dancing tango without heard or imagined music is nearly impossible, makes this conclusion plausible.

In order to resolve all the questions and vicious circles in relation to schema theory and its interdependence with cultural constraints a more detailed and experimentally corroborated theory is necessary than this admittedly uneven and loopholed sketch of an alternative starting point can be. Nevertheless it is hoped that at least it stimulates clarifying discussions about this central concept of cognitive psychology.

These ideas have gained much from David Rumelhart's lectures and discussions with Jennifer Freyd and Regine May. The remaining lack of clarity must totally be contributed to the author