Time Structure and the Structure of Perception

Markus Werning, Düsseldorf, Germany

1. The Perceptual Foundation of Knowledge

Our knowledge about the world is grounded in perception; and a good share of it is based, on visual perception in particular. Due to psychological and neuro-scientific research more and more details are being disclosed about the internal causal process that starts off with rather meager optical images on the retina and ends up in beliefs about the world. As philosophers, however, we must not be content with an exploration of the causal chain between those tiny optical projections on the eye's inside and the complex, conceptually structured representation that makes up the body of our empirical knowledge. What we have to evaluate, in addition, is the epistemic quality of this process; and in this regard what matters is precisely the course of justification. The stations of this course aren't just states of the brain, but states of the mind. Concerning the perceptual foundation of empirical knowledge, what's of particular epistemic interest are the starting points in this course of justification: those states of the mind that are commonly called epistemically prior. Since the optical images on the retina, for sure, are merely neuronal rather than mental, they don't qualify as epistemically prior, although they are causally prime.

Within the empiricist tradition, however, there's always been a strong appeal for pictures that do count as mental and do precede mental judgments. Those views include the extreme positions of the British Empiricists (Locke, Berkeley, Hume) who held that "all thought consists in the manipulation of either simple images derived from sense experience or complex images built up from these simple images" (Tye 1991, p. 5). They also include the more moderate positions of the Logical Empiricists. Carnap (1928), e.g., begins his logical reconstruction of propositional knowledge with a classification of pictorially analyzable sensations.[1] It is the Empiricist Priority Thesis I will question in this paper:

> *Empiricist Priority Thesis*
> In the course of the perceptual justification of knowledge, pictorially structured mental representation precedes conceptually structured mental representation.

In my criticism I will take recourse to recent findings on the time structure of neuronal responses in the visual cortex.

2. Representation

What is representation? Due to space and time limits, we have to restrict ourselves to a rather preliminary and largely stipulative account here.[2] In most general terms, representation can be conceived of as a mapping between two relational structures: a representing structure A and a represented structure B. Each structure X consists of a set of carrier elements El^X and a set of relations Rel^X that are defined on the carrier set. To make this mapping a representation, two additional conditions must be met.

First, relations between the representing elements should somehow reflect relations between the elements represented. In formal terms, this is to mean that the mapping from A to B – say, μ with $\mu[El^A]=El^B$ and $\mu[Rel^A]=Rel^B$ – should be a homomorphism from A to B. That is, for each n-ary relation R of A and any sequence $x_1, \ldots, x_n$ of A-elements, there is an n-ary relation μ(R) of B such that the state of affairs

$$R\langle x_1, \ldots, x_n\rangle$$

in A is said to (μ-)represent the state of affairs

$$\mu(R)\langle \mu(x_1), \ldots, \mu(x_n)\rangle$$

in B.

Ten knots on a horizontal rope may, e.g., be said to represent the numbers 1 to 10 because the set of knots together with the relation being-right-to constitutes a structure that is homomorphous to a structure that contains the first ten natural numbers together with the successor relation.

Second, representation carries information. A relational fact in the representing structure indicates what is thereby represented to be true. For our purposes it suffices to use the basic notion of indication as the relevant notion of information. We say that a state of affairs S carries information about a (therefrom metaphysically independent) state of affairs S* given the background H, if and only if what is true of S is probabilistically dependent on what is true of S*. If we spell this out for any representing state of affairs $Q = R\langle x_1, \ldots, x_n\rangle$ with respect to the thereby represented state of affairs $Q^* = \mu(R)\langle \mu(x_1), \ldots, \mu(x_n)\rangle$, we require for any representational system that the following inequality hold – with Pr(p|q) being the probability of p on condition q:

$$Pr(Q^*|Q \wedge H) > Pr(Q^*|H).$$

That is, a system is called representational with respect to some mapping μ just in case the system's being in a certain state of affairs of μ's domain increases the probability of the μ-represented state of affairs to hold true, given some background H.

3. Pictures in the Brain

Pictures are a species of representation for which, characteristically, adjacency and part-whole relations between the represented elements are preserved by the representing elements (cf. Gottschling 2003). Adjacency and part-whole relations can be defined in purely topological terms. All we need is to assign a topological space to the representing and represented structure each, such that every element of each structure can be assigned to a set of points in the respective topological space. Using the topological notions of neighborhood and connectedness, we can define the adjacency and the part-whole relation for any two elements, a and b:

> *Adjacency*
> a is adjacent to b (in symbols a||b) if and only if the union of any neighborhood of a with any neighborhood of b is connected.

[1] Both relations characteristic for pictorial representation, viz. the part-whole relation and the adjacency relation (see below), are either implicitly or explicitly assumed to hold at least among the qualities of the visual sense according to Carnap (1928, §77 and §89).

[2] The view on representation I am presenting here is elaborated by Bartels (2002).

Part
a is a part of b (in symbols $a \sqsubset b$) if and only if any neighborhood of b is a neighborhood of a.

We can now say that a representation μ is pictorial just in case the following holds:

(i) The representing structure A has a substructure with the carrier El^A and the thereon defined relations || and $\sqsubset$.

(ii) The represented structure B has a substructure with the carrier El^B and the thereon defined relations || and $\sqsubset$.

(iii) Adjacency relations in the representing structure indicate adjacency relations in the represented structure, i.e., $Pr(\mu(a)||\mu(b) \mid a||b \wedge H) > Pr(\mu(a)||\mu(b) \mid H)$, for any a and b in El^A and background H.

(iv) Part-whole relations in the representing structure indicate part-whole relations in the represented structure, i.e., $Pr(\mu(a) \sqsubset \mu(b) \mid a \sqsubset b \wedge H) > Pr(\mu(a) \sqsubset \mu(b) \mid H)$, for any a and b in El^A and background H.

This definition not only applies to naturalistic pictures in central perspective, but also, for example, to Picasso's famous cubist painting *Woman with a Mandolin* (see figure 1).

Figure 1. Woman with a Mandolin (Picasso 1910).

In the center of the upper third of the canvass we see an oval patch of gray, which we recognize as representing an eye. It is surrounded by an edgy area of white, which, together with other colored areas, apparently represents the head. According to our topological definition, the oval is a part of the edgy area. As it should be, this indicates that what is represented by the oval, viz. the eye, is a part of what is represented by the edgy area, the head. In the lower half of the painting we see a lengthy stripe of dark color, which is tilted to the right. On its upper right it touches a white area with a zigzag fringe. The dark colored area being adjacent to the white zigzag area represents the woman's left hand being adjacent to the mandolin's neck. The preservation of part-whole and adjacency relations is crucial to an understanding of the representational capacity of pictures. How else could we identify color patches on Picasso's painting as representing elements of the scene if we did not draw on the complex topological relations among them?

Notice that our definition of pictorial representation is supposed to be minimal. It is general enough to cover not only paintings, photographs and the like, but also maps, many diagrams and maybe even acoustic representation like that of shellac records. The definition is not dependent on a notion of geometrical or metric space. It may, however, well be enriched in this respect.

Kosslyn (1994) and other contemporary defendants of the Empiricist Priority Thesis point to neurobiological evidence for pictorial representation in the cortex. Thus, figure 2 shows a chunk of the primary visual cortex of a macaque that was stimulated with a complex circular object. Due to a voltage sensitive dye, one recognizes a particular pattern of high and low neuronal firing rates in the chunk of cortex. Although metric relations have not been preserved, the chunk of cortex exhibits a topological structure of adjacency and part-whole relations among clusters of neurons with high and low firing rates. This structure, as can easily be seen, (probabilistically) corresponds to the structure of adjacency and part-whole relations among the dark and light patches in the stimulus. According to our definition, the claim that the cortex exhibits pictorial representation is, hence, indeed justified. More problematic, however, is Kosslyn's interpretation of the neurobiological data as indicating that there also is pictorial representation in the mind. To this claim we will get back later.

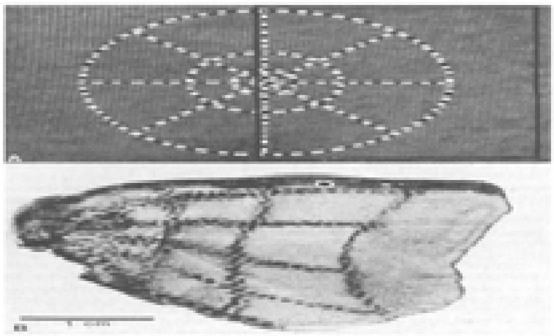

Figure 2. During stimulation with a circular object (left), a piece of macaque primary visual cortex (right) was exposed to a voltage sensitive dye. Dark (light) color indicates a high (low) firing rate of the dyed neurons. Reproduced from Kosslyn (1994).

4. Concepts and Time Structure

About 20 years after that topological structure had been found in the cortex, another radically different structure was discovered in the very same cortical region: the structure of object-related neuronal synchronization. This discovery has frequently been proposed as a solution to the so-called binding problem (Treisman 1996): The brain processes information of different feature dimensions in different areas. In some areas neurons are, e.g., responsive to particular colors, whereas neurons of other areas characteristically respond to specific orientations. In order to discriminate between a stimulus that consists of a red vertical object next to a green horizontal objects and a stimulus that shows a green vertical object next to a red horizontal object, the brain must bind the feature information together in an object-specific way. For this purpose, von der Malsburg (1982) postulated a mechanism of synchronization: Neurons that code for features of the same object synchronize their oscillatory electrical discharges, while neurons that code for features of distinct objects fire in asynchrony. This prediction was experimentally confirmed by single-cell recording and other methods in mammals and humans (Gray, et. al. 1989; Singer 1999). The findings were simulated (Schillen & König 1994) and analyzed (Maye & Werning 2004) by means of so-called oscillatory networks. The data, simulations and analyses suggest the existence of conceptually structured representation in the cortex: the neural basis of object concepts are oscillatory patters of neuronal discharges and the neuronal basis of property concepts are clusters of feature-specific neurons. A property concept is predicated of an object just in case the oscillatory pattern of activity that represents the object pertains to the cluster of neurons that are selective for the property in question. Unlike Kosslyn's topologically structured patterns of neuronal firing rates, the time structure in the neuronal responses can be regarded as a structure of conceptual representation.

Conceptual representation is a case of representation for which the compositionality of meaning and content is essential. This has to do with the fact that concepts fulfill two purposes: they provide meanings to the expressions of predicate languages and they provide content to intentional states (Fodor 1998). As given we take the syntax of a predicate language $L = \langle El^L, Rel^L \rangle$ consisting of a set of terms El^L and a set of syntactic relations Rel^L (at least, conjunction, disjunction, implication, negation, predication and universal as well as existential quantification). Let the language, furthermore, have a denotation function ν and a homomorphous denotation structure D with the denotations of the terms of L in $El^D = \nu[El^L]$ and the corresponding relations in $Rel^D = \nu[Rel^L]$. Then a structure $C = \langle El^C, Rel^C \rangle$ is called a conceptual structure if and only if the following conditions hold:

(i) There is a compositional meaning function μ from L to C. That is, if a certain syntactic relation R of Rel^L holds between a complex term t_n of El^L and its syntactic parts t_1 to t_{n-1} of El^L, then the relation $\mu(R)$ holds between the meaning of the complex term and the meanings of its syntactic parts:
$R\langle t_1, \ldots, t_n \rangle \rightarrow \mu(R)\langle \mu(t_1), \ldots, \mu(t_n) \rangle$.

(ii) There is a compositional content function κ from C to D. That is, if a certain relation Q of Rel^C holds between a complex concept c_n of El^C and its parts c_1 to c_{n-1} of El^C, then the relation $\kappa(Q)$ holds between the content of the complex concept and the content of its parts:
$Q\langle c_1, \ldots, c_n \rangle \rightarrow \kappa(Q)\langle \kappa(c_1), \ldots, \kappa(c_n) \rangle$.

This is a relational account of the compositionality of meaning and the compositionality of content. It is equivalent to the functional notion of compositionality according to which the meaning (*mutatis mutandis*: content) of a complex term (concept) is a syntax-dependent function of the meaning (content) of its parts (Hodges 2001, Werning 2003). Notice that the content of a concept is here identified with the denotation of the term whose meaning the concept is. Again, our definition of conceptual structure is supposed to be a minimal definition that might be enriched by further conditions. Elsewhere I have shown in detail that the structure of object-related neuronal synchrony satisfies the conditions (i) and (ii) (Werning 2005).

5. Binocular Rivalry and Awareness

In the light of the neurobiological data, one might conclude that, on the same cortical level, viz. in the primary regions of the visual cortex, both a pictorial and a conceptual structure of representation is realized. The former consists of topological patters of firing rates, whereas the latter is based on a time-structured pattern of synchronous and asynchronous discharges. But what does this imply for the structure of perception? Do the data support or defeat the Empiricist Priority Thesis? To decide these questions, we have to ask which of the two structures correlates with awareness. For, only contents of which the subject is aware are in the mind and thus may play a role in the course of the perceptual justification of knowledge.

An experiment that exploits the phenomenon of binocular rivalry might give us a hint. If one exposes the two eyes of a subject to incompatible stimuli, only one of the two stimuli becomes aware at a time. In subjects with strabismus one eye is dominant over the other such that the outcome of the binocular rivalry is predictable: Usually, the stimulus presented to the dominant eye becomes aware, while the second, incompatible stimulus remains unaware. Engel and Singer (2001) exposed strabismic cats to rival stimuli and measured the extent of firing rates as well as the degree of synchronization among the neurons that respond to the stimuli in either hemisphere. For the left eye they chose leftward moving vertical bars while the right eye was exposed to rightward moving vertical bars. From the cat's eye saccades they could read off which stimulus the cat was currently aware of.

The cell recordings provided the following results: If only one eye is stimulated, both the firing rates and the synchronization of the responding neurons in the respective hemisphere increase. If the two eyes are exposed to rival stimuli, the firing rates, too, increase in both hemispheres despite the fact that only the hemisphere of the dominant eye produces awareness of the moving bars as can be read off from the saccade behavior. The neuronal synchronization, however, only increases among the neurons responsive to the dominant eye, whereas the discharges in the hemisphere of the suppressed eye are almost completely de-synchronized. It thus turns out that the distribution of firing rates does not correlate with awareness, while the structure of neuronal synchronization and de-synchronization does.

6. Conclusion

Neurobiological data suggest that in cortical regions involved in early visual processing, pictorial as well as conceptual representation is realized. The former is made up of topological patterns of firing rates which are informationally related to topological patterns in the stimuli. The latter consists of a time structure in the discharges of neurons. The patterns of object-related synchrony and asynchrony among clusters of neurons provide a compositional representation of state of affairs that can be denoted in predicate languages. Cell-recording experiments on binocular rivalry with strabismic cats, however, suggest that only the time structure in the cortex, which may be identified with conceptual representation, contributes to awareness and may thus play a role in the perceptual justification of knowledge. The topological and, hence, pictorial representation in the visual cortex may play an important role in the causal production of knowledge. However, with regard to justification it remains inert. For, it does not correlate with awareness and does not provide contents to the mind. From an epistemological point of view, the prior epistemic processes of perception are conceptual rather than pictorial. The Empiricist Priority Thesis seems hardly tenable.

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Markus Werning <werning@phil-fak.uni-duesseldorf.de>