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Miracles of perception

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Abstract

This paper draws a bird's eye view of various counter-intuitive characteristics of perception. Peculiar is that perception is a both tool and topic of its study. As a consequence, its output is easily mistaken for its input. Furthermore, its output is characterized by remarkable Gestalt features, such as mutual dependence of stimulus elements and detour solutions. Detour solutions require a complex perception process of testing countless optional pattern interpretations against a criterion. Likelihood is a plausible criterion for reasoning. For perception, however, the simplicity criterion is more appropriate. The consideration is that reasoning aims at establishing properties of distal objects whereas perception aims at establishing objects from proximal properties. The role of knowledge in perception seems plausible but often leads to conflicts. For instance, the assumption that knowledge about handedness is present in pattern representations conflicts with image mirror-image discrimination data. Moreover, knowledge does not provide an anchor for subjective time direction, but a Gestalt quality does.

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1. Introduction

Epistemology has been and still is the main topic of study in science, from ancient philosophy to recent psychology. In general, it deals with cognition including perception, but especially perception has been a source of dilemmas that gave rise to furious debates. Here, I review only several dilemmas that were raised by various Gestalt studies. My approach, however, is lateral. This means that I first consider a few

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miracles beyond the domain of perception, to highlight properties they have in common with perception.

2. Evolution

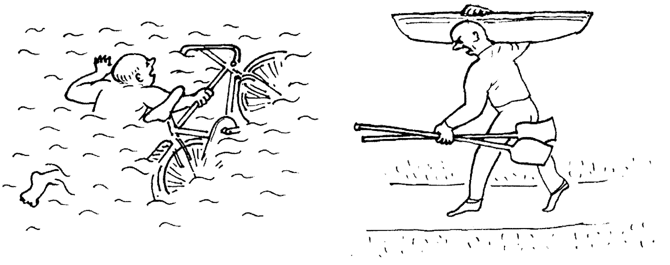
The DNA chain of a cat contains various inconspicuous subchains that underlie phenomenal features such as hair colour, suppleness, character, cleverness. It is true that a minor DNA disturbance might change a cat into a sick monster, but the actual chain fixates a healthy cat over innumerous generations. Another miraculous aspect of evolution is the development of mutually dependent functions. For instance, the cat's claws to catch a mouse and the cat's specific ability to digest a mouse. The evolution of these mouse-oriented dispositions presupposes the cat's recursive ability to reproduce itself. Inversely, to maintain itself, this reproductive ability also presupposes these mouse-oriented dispositions. The question is how these mouse-oriented dispositions and, even more, this reproductive ability—in itself an extremely high-tech machinery, complementary distributed over females and males—can be the outcome of evolutionary accidentalities. The assumption by Simon (1969) of a stepwise evolution process, proceeding first to a low-life equilibrium and subsequently to higher-life equilibria, reduces the explosive amount of selection alternatives indeed but leaves the mystery of evolution still largely intact.

About the course of evolution, a remarkable finding stems from Bolk (1926). The common expectation is that young specimens adopt features of adults of the preceding generation. However, Bolk's study on monkeys, both with respect to physiological and behavioral aspects, shows an opposed development. Adults adopt features of young members of the preceding generation. For instance, a young monkey is less hairy than an adult and, over generations, monkeys indeed show a decreasing hair growth. Also for the cognitive development Bolk's view seems to be supported. General multipurpose knowledge perhaps is hereditary but specific acquired knowledge certainly is not. Apparently, evolution tends towards the tabula rasa of a naive young mind that is adaptive to ever-changing circumstances and not towards an adult's expert knowledge that is adapted to only a specific fixed world.

3. Problem solving

Cognition too is a remarkable and complex process. It even shares some of the mentioned features of its own evolution, even though there is an obvious time scale difference: evolution is a macro-genetic process of millions of years whereas reasoning is a process of seconds and perception a process of milliseconds.

I first consider reasoning involved in problem solving. There are various wonderful riddles characterized by spectacular solution features. Here, I show that such features even characterize a normal task, for instance, the task to go to the other side of a lake. A shortest path solution is to cross the lake with a canoe plus peddles. Another solution is to use a bike and to cycle along the road around the lake. In general,



(A) (B)

Fig. 1. Two examples of transport, in which the ingredients are appropriate but the combinations inappropriate. In A, water is combined with a bike. In B, the road is combined with a canoe and peddles.

the quality of a solution depends on how ingredients are combined. For instance, in itself, the bike is a useful conveyance and, in itself, the water is an appropriate medium, but the combination makes no sense (Fig. 1A). Equally bad is to take the road with a canoe plus peddles (Fig. 1B). This case is indicated by

good + good = bad.

Of more relevance is the reverse where tools, that are bad if taken separately, can be useful in combination. For instance, a canoe without peddles is useless, and so are peddles without a canoe, but the combination is useful. This case is indicated by

bad + bad = good.

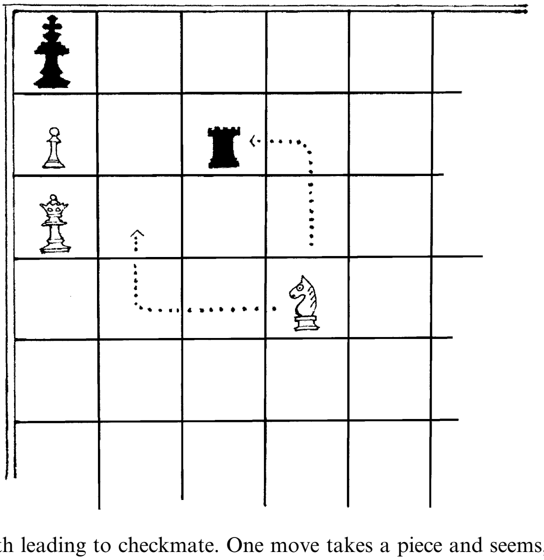


Fig. 2. Two moves both leading to checkmate. One move takes a piece and seems, therefore, more save. The other move seems more risky but is, therefore, more aesthetic.

This kind of "detour" solutions, especially, is characteristic of perception too. Such solutions do not follow directly from the available ingredients as such, but from their mutual interaction. Another typical illustration of a detour solution is the construction of a hut frame by means of three tilted piles. In itself, each pile is unstable. However, their combination is stable and efficient.

Intriguing art products and solutions of funny riddles, especially, reveal detours. Art is supposed to be characterized by the use of minimal means that are improbable with respect to its effects (Boselie & Leeuwenberg, 1985). Fig. 2 presents an illustration that combines aesthetics with a riddle. It illustrates two chess moves both leading to checkmate. The first option seems more save, as catching a piece is usually taken as a positive step toward winning the game. The second option seems more risky. Therefore, the latter option is more aesthetic (Margulies, 1977).

4. Invisible perception

Before discussing detour solutions in the visual domain, I first focus on a general characteristic of perception. Almost all textbooks introduce perception by exposing illusions. Indeed, illusions are salient illustrations of visual effects but do not deal with the core issues of perception. These core issues are hardly penetrable and often counter-intuitive, for the following reason.

In perception research, perception plays a dual role. It is both mediating instrument and topic of study. As a mediating instrument, perception is involved in observations. In fact, any kind of research makes use of observations, namely, with the goal to establish attributes of objects. For instance, an observation may establish that leaves are green. Crucial is their colour. Whether the stimuli present real leaves is not an issue. In other words, for any kind of research and therefore also for perception research, objects belong to the input. However, for perception as a topic of study, this is not true. For perception itself, objects belong to the output. The input is an assembly of different patches of light at various positions on the retina. The visual process assesses which patches belong together and constitute objects, for instance, green leaves. Hence, research aims at establishing properties of distal objects, whereas perception aims at establishing objects from proximal properties.

Because objects are output of perception and input of perception research, the false suggestion may arise that objects are both output and input of perception. Then, however, perception would just turn objects into objects, which would imply that both the actual proximal input and the process towards the output are superfluous. Nevertheless, everyday experience of perception reinforces this false suggestion. There is no sensation of the proximal input as being an assembly of unstructured patches on the retina. Furthermore, the process of perception is rapid, effortless, and beyond any conscious control. Its output is not experienced as a mental construct but merely as an external scene one looks at. Such considerations inspired Aristotle (1957/350 BC) to make the following pessimistic prediction that, in my view, seems to be confirmed rather well:

In a shorter time more will be known about the most remote objects, namely the stars, than about the most nearby topic, namely perception.

5. Perception of the invisible

The number of perceptual miracles is actually so abundant that it even makes sense to explore a topic that is almost the reverse of the afore-mentioned topic, namely, perception beyond external stimulation. Here, I present four versions of this phenomenon, each with its own peculiarities.

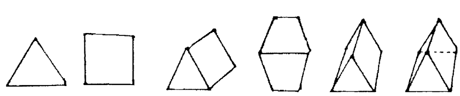
5.1. Dreams

Obviously, dreaming combines perception and missing external stimulation. Here, I illustrate a perceptual peculiarity of dreams, by means of the actual dream of a student (namely, myself). In this dream, the student was asked to guess a word the teacher had written on the rear of the black-board. He was unable to guess the word, so the teacher turned the black-board. Then, the student could read the word.

In the first stage of this dream, the word was simultaneously absent and present. The absence was in the mind of the student, that is, in the mind of the dreamed ego. The teacher knew the word from the very beginning, so, the presence was in the mind of the teacher and therefore in the mind of the dreamer.

5.2. Imagery

Another remarkable ability is imagery in the awake state. Although imagery and perception are closely related (Farah, 1995; Finke, 1980; Moyer, 1973), they obviously differ. Imagery is the ability to derive, without external stimulation, object features that are only implicitly present in the internal representation of an object. Imagine, for instance, a cube cut in half along its diagonal plane. The task is to establish for one part, without using paper and pencil, the number of edges that would be visible from various viewpoints. Usually, one is well able to assess the numbers: 3, 4, 6, 7, and 8 (see Fig. 3). One is also well able to imagine the object's rear and to assess that the object as such has nine edges in total.



3 4 6 7 8 9

Fig. 3. More or less coincidental views of the same object. The numbers refer to the number of visible edges in each view. Even without such pictures, one is well able to assess these numbers, namely, by imagery.

Obviously, imagery has its limitations but, often, an imagined object seems almost as vivid as a real object. Yet, it is certainly not true that the image consists of a real object that can be turned in our mind. It seems that only one specific object view is imagined but, remarkably, imagery seems to take this single view as a representative of a class of object views that give the same number of visible edges (Hinton & Parsons, 1981; Moran, 1968).

5.3. Attention

Missing stimulus aspects may yet be perceived due to attention. For instance, if attention is focused on a light gray area and not on an adjacent dark gray area, the light gray area appears visually brighter and, if the focus is on the dark gray area, its gray appears visually darker (Festinger, Coren, & Rivers, 1970). To put it simply, attention enhances visual target contrast. Remarkably, also the reverse occurs. An increase in stimulus contrast gives rise to an increase in attention: increased stimulus brightness of the light gray or decreased brightness of the dark gray gives the changed part more "Figure" quality, that is, gives rise to increased attention to the changed part (Festinger et al., 1970). This mutual interaction between effect and cause of attention shows that attention is not independent of perception.

Another demonstration of such a mutual interaction between cause and effect deals with motions. If one attends to the moon while the clouds move, the moon seems to move and the clouds seem stable (Johansson, 1975; Restle, 1979). Thus, attention induces motion. Again, also the reverse happens: motion induces attention. After all, moving stimuli attract more attention than stable stimuli.

5.4. Completion

Finally, occlusion patterns trigger a form of pattern completion that fills in invisible parts of an object (see, e.g., Gerbino & Zabai, 2003). Obviously, this completion requires a detour with respect to the proximal stimulus. Studies by Gerbino and Salmaso (1987), Sekuler and Palmer (1992), and van Lier, van der Helm, and Leeuwenberg (1995) provide experimental evidence for the claim that this completion is a visual phenomenon. This implies that visual solutions involve detours. Besides, this claim is also plausible without experiments, for the following reason. There is no doubt that subjective contours (Ehrenstein, 1941), neon effects (van Tuijl, 1975; Varin, 1971), assimilation and transparency effects (von Bezold, 1874) are phenomena within the visual domain. All these phenomena can be considered as versions of pattern completion (Rock, 1983). Hence, it is implausible that pattern completion in the case of occlusion would not be visual.

My general conclusion is that not only problem solving but also perception uses detours. In fact, detours are the main characteristics of the so-called "Gestalt", that is, the visual form that is underdetermined by its visible parts (Koffka, 1935; Wertheimer, 1923).

6. Rivalry among solutions

Especially the detour characteristics of visual pattern representations motivated Herbart (1850) to reject the idea that perception is a simple process of stepwise inferences that, without considering alternatives, straightforwardly leads to single solutions. Instead, he assumed a competition between all possible solutions and a criterion to select the winning solution. This criterion is formulated goal-directed in terms of process outcomes, and not method-directed in terms of process mechanisms (Hatfield & Epstein, 1985).

Also Gestalt cues are compatible with Herbart's view of perception. Indeed, in case various Gestalt cues apply to one pattern and predict contradictory organizations, a priority rule would be useful. The rule that, for instance, proximity always overrules good continuation, and the latter always overrules common fate, would yield unique solutions. However, perception misses such rules. A reason is that not only the quality (e.g., proximity or good continuation) but also the quantity (e.g., the degree of proximity) of each Gestalt cue determines its strength. Hence, to determine the strongest solution, all cue quality–quantity combinations have to be compared and tested against an overall selection criterion.

As said, the selection criterion applies to process outcomes and not to process mechanisms. Hence, Herbart's proposal risks being incompatible with a model that uses a process criterion, such as the global precedence hypothesis of Navon (1977). Indeed, this hypothesis gets support for 2-D configurations of separate subpatterns (Hoffman, 1975; Navon, 2003) but under various restrictions such as the visual angle (Kinchla, 1977), the number or size of the subpatterns (Martin, 1979), the kind of subpatterns (Kimchi & Palmer, 1982), and the colour (Beck, 1982). In fact, these restrictions presuppose a preliminary stage that, before the global to local processing takes place, first establishes whether the stimuli are appropriate compound texture-like configurations within the above restrictions. The odd implication is that such a preliminary stage of stimulus classification would precede the very stages that are supposed to establish stimulus classification. Even if there are stages of perception there is no evidence for a fixed processing order, be it from global to local or from local to global (Pomerantz et al., 2003). For Gestalt formation, a similar conclusion is drawn by Palmer, Brooks, and Nelson (2003): grouping principles are involved in all stages.

Without doubt, the global precedence hypothesis applies to the perceptual domain of art production. Painters and music composers often begin with a global sketch and end with elaborating details. This order is efficient as the global shape can be drawn without subpatterns, whereas subpatterns cannot be drawn without their positions determined by the global shape. However, art creation is opposed to perception. Art creation deals with the process from representation to pattern whereas perception deals with the process from pattern to representation.

Of course, Herbart's proposal also has its implausible side. The perception process that turns a retinal mess of unrelated patches into an ordered structure is assumed to generate innumerable solutions that are compared with each other to select the best one. The complexity of this process contrasts to its speed. Perception

Fig. 4. A demon picking out milk from a milk–coffee mixture. His job is as complex as the job of perception: it starts from chaos and ends with order.

needs just a few milliseconds for this process from chaos to order. Pouring milk in coffee, for instance, also requires only a few milliseconds, but is a process from order to chaos. In fact, the little Maxwell demon in Fig. 4 performs a process from chaos to order that is as complex as the perception process. He segregates milk from a milk–coffee mixture, that is, he picks out milk molecules one by one. In contrast to perception, a usual demon needs about 1000 years to fulfill such a job.

7. Likelihood criterion

Without doubt, the best theory is the one that adequately predicts reality. Hence, likelihood is the obvious criterion for science. According to Pomerantz and Kubovy (1986), it is also appropriate for perception. However, I question this. After all, as said, science and perception differ: science aims at establishing properties of distal objects whereas perception aims at establishing objects from proximal properties.

To test the likelihood criterion for perception, I consider Fig. 5. It presents two proximal stimuli, each with two options. The cross stimulus A either stems from the single cross object C or from the two small sticks D, and the long-line stimulus B either stems from the single long stick E or from the two small sticks D. First, I focus on the question of whether interpretation D fits in better with stimulus A or with stimulus B. Then, I focus on the question of whether, compared to interpretation D, interpretations C and E fit in better with stimuli A and B, respectively. Both questions apply to the conditional component in Bayes' rule—I address the unconditional component subsequently.

First, without doubt, the cross stimulus is more preferably perceived as a composition of two small sticks than the long-line stimulus is. The explanation by Rock (1983) is that throwing two sticks has a higher probability of resulting in two crossing sticks than of resulting in two aligned sticks. For the unique concrete configurations A and B, however, this is not true: then, the two probabilities are about equal.

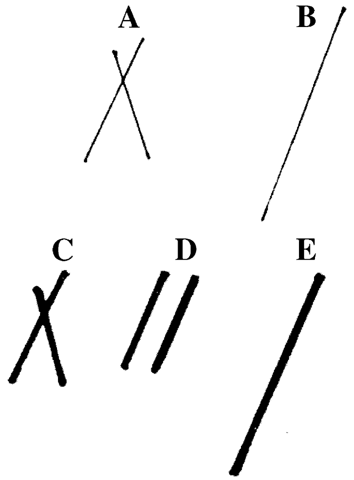


Fig. 5. A and B depict proximal stimuli; C, D, and E depict distal stimuli. The question is whether likelihoods explain, first, that the two-object interpretation D is more plausible for A than for B and, second, that D is less plausible than the single-object interpretations C and E.

Only if each stimulus is taken to represent a class of sticks with the same regularity structure, the two probabilities differ: the class of crossing sticks is larger than the class of collinear sticks. After all, a composition of crossing sticks is less regular than a composition of collinear sticks is. Hence, not the likelihood but the assessed regularity explains why A, rather than B, is perceived as two small sticks (Leeuwenberg & Boselie, 1988; van Lier, van der Helm, & Leeuwenberg, 1994).

Second, taken as a unique stimulus, A rather stems from a single object (C) than from a pair of small sticks (D). Similarly, taken as a unique stimulus, also B rather stems from a single object (E) than from a pair of small sticks (D). If we assume that, a priori, the options C, D, and E are all equally valid candidates, then the single-object interpretation of A would be preferred, and so would the single-object interpretation of B. Hence, the conditional likelihood disfavors the two-sticks interpretation for both A and B to the same extent. The remaining question now is what the unconditional likelihood would predict.

There are two versions of unconditional likelihood. One deals with the actual objects in the world. Assumed is that information about these objects and their frequencies is stored during evolution, is hereditary, and guides perception. However, objects are the outcomes of perception. In other words, in this version, the outcomes of perception are supposed to guide perception towards its outcomes. This would imply that perception explains perception (Hoffman, 1996) and that, at least at its origin, perception must have had a serious handicap (van der Helm, 2000). Another version of unconditional likelihood deals with retinal images and thus avoids circularity. After all, both present perceivers and all their ancestors deal(t) with retinal images. In all other respects, this second version agrees with the first version.

Assuming this second version of unconditional likelihood, I return to Fig. 5. In general, it holds that both crossing-lines images and long-line images consist of many short-line images whereas short-line images do not consist of crossing-lines images or long-line images. Hence, more short-line images are stored than crossing-lines images or long-line images are. This unconditional likelihood would therefore favor the two-sticks interpretation for both stimuli A and B. It may even overrule the earlier-discussed conditional likelihood.

In conclusion, both conditional likelihood and object-based unconditional likelihood are circular and miss explanatory power. The image-based unconditional likelihood avoids circularity but merely suggests a process from input to input: it favors mini-element, say pixel, interpretations instead of Gestalt percepts. Moreover, both the object-based and the image-based unconditional likelihoods assume that knowledge is hereditary over generations. There is, however, no evidence for this assumption.

8. Simplicity criterion

Conscious reasoning establishes propositions that might be false or true. Propositions both comprise objects and predicates. Perception, however, merely establishes objects and it makes no sense to attribute false or true qualities to mere objects (Sober, 1975). For instance, the proposition "leaves are green" might be true or false, but the perceptual assessment "green leaves" is neither true nor false (Gibson, 1966). Therefore, in my view, perception does not aim at likelihood and veridicality (see also Hatfield, 2003). For perception, an internal criterion such as accuracy or simplicity is more appropriate.

Suppose that maximal accuracy is taken as a selection criterion. It is obvious that a pattern description is inaccurate if it represents different elements as being identical. It is also inaccurate if it represents identical elements as being different. For instance, a description of a square that disregards the equality of lines and of turns is inaccurate. In fact, this description is equivalent to that of an arbitrary quadrangle (Collard & Buffart, 1983). In general, a description can be made more simple by describing more identical pattern elements as being identical, which, in turn, implies a higher accuracy. Hence, the simplicity of a description reflects its accuracy (van der Helm, 2000). Moreover, as a perceptual selection criterion, the simplicity principle agrees with the Law of Prägnanz proposed by Koffka (1935).

The simplicity principle applies only to structural aspects of patterns. These aspects should be discerned from metrical aspects. Structural aspects deal with global categories: elements are different or equal. Metrical aspects deal with quantitative variations within these categories. Fig. 6 illustrates this difference. The left figure presents an elephant structure with the metrical proportions of a human. The right figure presents a human structure with the metrical proportions of an elephant. In my view, a visual pattern description represents both a class of patterns and the actual stimulus (Garner, 1974). In fact, pattern representations combine structural and metrical aspects just as a mathematical equation does. Consider, for example, the equa-

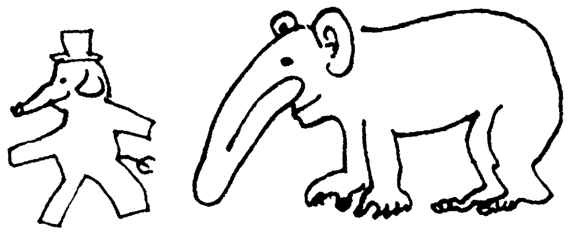


Fig. 6. Structural versus metrical properties. A depicts an elephant structure with the metrical proportions of a human. B depicts a human structure with the metrical proportions of an elephant.

tion $Y = aX + b$. If a and b stand for metrically variable parameters, the equation describes a class of patterns with a line structure, and if a and b stand for specific metrical values, the equation describes a specific line.

9. Knowledge

The earlier-discussed likelihood principle—that presumes effects of knowledge supposedly acquired during evolution—is, in fact, a phylogenetic version of the likelihood principle. Here, I discuss an ontogenetic version based on knowledge acquired during one's life. The role of this knowledge seems compatible with everyday experience of perception. For instance, we recognize a face of a family member within a glance. During this brief period, however, there is no experience of two stages: a first stage of processing the retinal stimulus toward the representation of a specific 3-D structure, and a second stage of matching this structure with memory content resulting into recognition. Note that an internal criterion like simplicity assumes a first, autonomous and impenetrable, perception stage and a subsequent recognition stage.

In general, everyday perceptual experience supports the assumption that perception is affected by context, knowledge, attention, motives, and planning actions, and that perception should not be studied in isolation but in relation to all these high levels of cognition. Of course, one is free to define perception in this broad sense. However, a relation makes no sense beyond the related elements. That is, the study of a relation can prosper only by the study of the related elements separately. Moreover, various microgenetic experiments by Bachmann and Allik (1976) and Mens and Leeuwenberg (1988) show a level of form perception that is not affected by context. They conclude that knowledge only affects the output of perception, that is, only in the post-perceptual stage of recognition (Kanizsa & Gerbino, 1982).

The same conclusion is drawn by Rock (1985) from his observation that only ambiguous patterns are sensitive to context, in the sense that context may disambiguate such patterns. His argument is that, if this context effect would be the result of perception, then perception would lead to both ambiguity and non-ambiguity. To avoid this contradiction, the assumption can be made that ambiguity is due to perception and that this context-based non-ambiguity is due to a post-perceptual process of knowledge-based expectation that merely enriches visual interpretations. Furthermore, note that the mere two or three interpretations in case of phenomenal ambiguity contrasts to the innumerous theoretically possible interpretations of any pattern. Almost all these theoretically possible interpretations are perceptually implausible and therefore not inducible by context. In other words, from this theoretical viewpoint, the domain of the just-discussed context effect is miniscule.

If perception would include knowledge, then it could exploit the efficiency of representations that consist of separate features. If, among known persons, only one has a long nose, for instance, then this long nose feature suffices to identify that person. However, separate-feature representations and visual codes (that integrate features) behave quite different, especially with respect to complexity (see also Strother & Kubovy, 2003). One argument is as follows. It is plausible that the complexity of a separate-feature representation is determined by the number of features in this representation. Furthermore, the more features are represented, the fewer members there are in the class of patterns described by the representation. Hence, for separate-feature representations, increasing complexity implies decreasing class size. In contrast, increasing complexity of visual codes implies increasing class size. Remember Fig. 5: a cross is more complex than a stick and the class of crosses is also larger than the class of sticks (Garner, 1970).

It is true that, if perception is guided by simplicity and not by knowledge, then the border of perception is a problem (Hochberg, 2003). However, if perception is guided by both simplicity and knowledge, there is a problem too, especially when simplicity and knowledge are contradictory. For instance, the retina receives almost only asymmetrical projections of symmetrical objects. Moreover, perfectly symmetrical objects hardly exist. Hence, the frequency of retinal occurrences of asymmetrical structures favors interpreting stimuli as projections of asymmetrical objects. However, perception yet tends to interpret asymmetrical projections of symmetrical objects as being projections of symmetrical objects (Wagemans, 1995).

Finally, if perception would be affected by knowledge, then its role would be unreliable for testing hypotheses (Goodman, 1972). Consider the hypothesis that all rats are black. If the observations to test this hypothesis are affected by this hypothesis itself, the extreme consequence is that a white rat is perceived as a black rat or as a non-rat. Hence, such observations would confirm any hypothesis (Fodor, 1983). Obviously, perception is not the end but the beginning of cognition.

10. Handedness

The issue here is not that 4-year old children know that left and right hands are opposite limbs, but that 6-year old children have knowledge of the hand's "handedness", namely, which is the left hand and which is the right hand. In fact, this topic exceeds the domain of hands. It also applies to 2-D patterns. For instance, consider the letter **b** and its mirror-image letter **d**. These letters are differently handed. Moreover, it may apply to 3-D objects, such as the clocks in Fig. 7. One clock is the mirror-version of the other, and also these two clocks are differently handed.

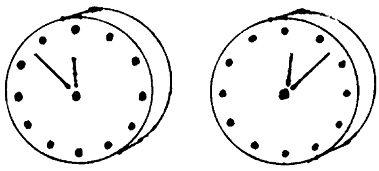

(A) (B)

Fig. 7. Taken as two objects, B is a mirror-version of A; the question is whether a knowledge-free perceptual cue exists to discern B from A. Taken as two views of the same object, B is later than A; the question is whether a knowledge-free perceptual cue exists to assess this temporal order.

Children have learned about handedness, for instance, by a mark on the left hand or on the right hand. In fact, handedness only can be learned in this stimulus-analogous and view-dependent fashion by means of a concrete asymmetrical mark. There is no conceptual definition of handedness (Freudenthal, 1962) and there is no view-independent distinctive cue for handedness (Deutsch, 1955). In line with these conclusions is the claim by Leibniz (1714/1979) that the difference between a shape and its mirror-version merely relies on a difference between viewpoints. His reasoning is as follows. Two-dimensional mirror patterns, like the letters **b** and **d**, are equal in 3-D space: the rear of one letter is equal to the other letter. His inference for 3-D objects is analogous. An object and its mirror-version are equal in 4-D space: the rear of one object is equal to the other object. In 4-D space, an object's rear actually agrees with its inside-out version. For instance, the inside-out of a left-hand glove agrees with a right-hand glove.

The crucial question now is whether visual shape representations contain handedness cues. If so, handedness discrimination would not need the mediation by mental rotation. However, this is contradicted by the experiments of Shepard and Metzler (1971), suggesting that representations do not contain handedness cues. Another, less obvious, argument has been given by Leeuwenberg and van der Helm (2000). They argued that mental rotation uses rotation cues for the rotation to be tested in handedness discrimination tasks—otherwise, innumerous rotations would have to be tested whereas the actual search for the appropriate rotation occurs immediately and effortlessly. They argued further that visual shape representations may contain rotation cues that, however, cannot be compatible with handedness cues. This too suggests that representations do not contain handedness cues. Therefore, first, I conclude that handedness does not belong to a perceptual category but, rather, to a memory category. Second, the foregoing supports the idea that visual shape representations are not stimulus-analogous descriptions but, rather, classifying and view-independent descriptions.

11. Time direction

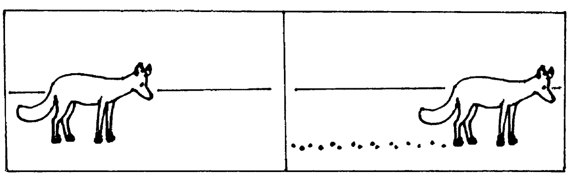
The two objects A and B in Fig. 7 can also be conceived of as one clock at different moments, but then another asymmetry arises: the direction of time from early to late. Everyone is aware of this time course but not of the cue for its forward versus backward direction. My concern here is not an objective but a subjective criterion for temporal order.

An obvious option is to take the natural tendency from order to disorder as criterion for time direction. However, note that this option is merely probabilistic and only characteristic for dead nature; it does not exclude rare reverse processes in dead nature and frequent reverse processes in living nature (Prigogine & Stengers, 1984). Furthermore, according to Ruyer (1956), this option can be tested for perception by showing a movie backwards. If this movie presents, for instance, a chaos of pieces turning into a building instead of a building that falls apart in pieces, the movie does not give rise to a sensation of time running backwards but merely to the conclusion that the movie is running backwards. Therefore, Ruyer dismisses this option.

Another option is the mark-asymmetry criterion, proposed by Reichenbach (1956) and earlier suggested by Descartes (1644/1953). This criterion stems from the phenomenon that a later event has a mark of the preceding event and not the other way around. Fig. 8 presents an illustration. It shows two samples of an event. Fig. 8A presents a fox and Fig. 8B presents a fox plus footprints. The usual conclusion is that Fig. 8A precedes Fig. 8B.

In my view, Reichenbach's criterion is promising, but to make it operational it should avoid accidental variables. One variable, that depends highly on a person's history, is his knowledge. Suppose he knows a fox as an animal that does not leave footprints, that follows the footprints of other animals, and that destroys these footprints by his tail while walking backwards. Then, Fig. 8B rather precedes Fig. 8A. Thus, a reliable criterion should avoid knowledge effects. Another source of variation deals with the phenomenal ambiguity of a stimulus. For instance, the dots in Fig. 8B probably are interpreted as holes (e.g., referring to footprints). However, if these dots are interpreted as convex objects (e.g., referring to pieces of fox food), then Fig. 8B may again precede Fig. 8A.

Avoiding such variations, Collard and Leeuwenberg (1981) proposed a version of Reichenbach's criterion for pairs of special figures. Fig. 9 presents such a pair. Fig. 9A is preferably interpreted as a mosaic (**M**) of two crosses and slightly less preferably as two overlapping (**O**) arrow shapes. Fig. 9B is quite unambiguous. It is merely interpretable as two overlapping (**O**) arrow shapes. The expectation is that, if Fig. 9B



(A) **(B)**

Fig. 8. A and B depict two snapshots of an event. The usually attributed time order is A–B. The reversed order B–A, however, may become plausible by knowledge influence or by an unusual perceptual interpretation.

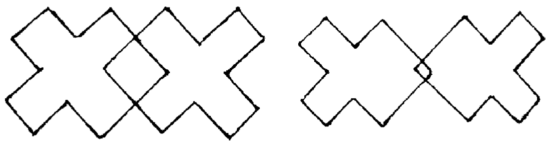


Fig. 9. A depicts a semi-ambiguous pattern (preferably seen as a mosaic, and less preferably seen as overlapping objects); B depicts an unambiguous pattern (only overlap). Ordered in time, only the A–B order reveals an identifiable event, namely, an interpretation change for A from mosaic to overlap. Therefore, in the absence of other time cues, A–B is the preferred order in subjective time order judgments.

precedes Fig. 9A, both figures evoke **O** interpretations. The argument is that this common interpretation reflects the simplest description of the two figures combined. However, if Fig. 9A is presented first, it initially evokes its preferred **M** interpretation but, after seeing Fig. 9B, it adopts its **O** interpretation. To test the role of this interpretation change, the experimental instruction was: "First you see two subsequent patterns during 5 ms. Then you see these two patterns simultaneously during 2 s. The task is to judge which pattern of the latter set was presented first during the preceding brief flash." In fact, however, this flash showed a single random pattern, so, subjects were actually invited to make up some order (they were not aware of this). The prediction was that Fig. 9A would be judged to be the first pattern because, only then, there is an identifiable difference between Fig. 9A and B, namely, the interpretation change. The actual judgments supported this prediction, which reveals a perceptual temporal order bias of simultaneously presented patterns according to Reichenbach's proposal about time direction.

The supported criterion is actually based on the relation between prototype and non-prototype. To clarify this Gestalt asymmetry, I turn to the domain of colours, with the focus on red and pink. Red is less ambiguous than pink. After all, pink is between red and white. As a consequence, pink is more like red than red like pink. Therefore, red plays the role of prototype, and is the primary reference colour for pink (Rosch, 1975; Tversky, 1977). Let us now return to Fig. 9. Fig. 9A is semi-ambiguous and Fig. 9B is completely unambiguous. Hence, Fig. 9B plays the role of prototype. Note that prototypes are primary categories that, however, do not necessarily precede non-prototypes in subjective time judgments. In cases where Reichenbach's mark-asymmetry criterion applies, prototypes do precede non-prototypes but, in Fig. 9 for instance, it is the other way around.

12. Summarizing remarks

Even if this paper would have been written a century ago, it would have contained hardly any news. Most ideas stem from ancient philosophy and psychology. The crucial question nevertheless is whether its claims are accepted. These claims seem incompatible with everyday experience of perception. In fact, this experience is quite absent. Only the outcome of perception is accessible. However, even this outcome is not experienced as the outcome of perception but as the external reality one looks at. That is, objects in reality are rather viewed as perceptual input with the consequence that perception is empty and eyes are just ornaments. At least, such conclusions may stem from everyday perception experience.

Of course, closing one's eyes prevents access to reality. Yet, imagery, dreams, and open-eye perception all fill gaps. Nevertheless, imagery and dreams are not supposed to deal with reality, whereas perception supposedly is—why so, and why not the other way around? Furthermore, to fill gaps, perception generates detour solutions, and precisely this most prominent Gestalt property requires a process of testing all possible solutions against a criterion. The complexity of this process contrasts with the speed of perception. If the criterion is simplicity, there is an extra contrast, namely, between the complexity of the process and the simplicity of the goal. These contrasts are true miracles of perception.

About 24 h a day, perception is at hand—like a close friend. Indeed, like an unavoidable and reliable friend, but unlike a docile adherent. Perception is more like an autistic stranger that disregards the perceiver's wishes and beliefs. Indeed, reliable perception provides the knowledge for testing wishes and beliefs but without being biased by them. To this end, perception makes no use of ontogenetic knowledge acquired during the perceiver's life. Besides, it hardly makes use of phylogenetic knowledge acquired during the perceiver's evolution. It does not aim at likelihood and at being adapted to a fixed world. Instead, it aims at being adaptive to ever-changing circumstances.

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