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Visual Search and Quantum Mechanics: A Neuropsychological Basis of Kant's Creative Imagination

Uri Fidelman

Technion, Israel Institute of Technology

This study analyzes the triple relation between cognitive biological psychology, philosophy and quantum mechanics. It discusses the findings of Treisman according to which there exists a pre-conscious cerebral mechanism that manipulates the sensory input and transfers it to our consciousness only after correcting it to suit our logic and expectations. This experimental finding was predicted two centuries ago by Kant. It is observed that during the primary pre-conscious level of perception the macroscopic physical world is not perceived as behaving according to the laws of classical physics but rather according to the laws of quantum mechanics, like the microscopic world.

Keywords: Kant's creative imagination, illusory conjunction, collapse of the wave function

This study concerns the relation between a biological system, the central neural system (CNS) and the image of the physical world, as it is perceived by our consciousness. Does our perception represent raw sensory data faithfully, or are these data manipulated by the biological system before arriving at our consciousness? This problem pertains to Kant's (1781, 1783) differentiation between the objective "things as they are in themselves" and "experience." Experience, or physical experience, is defined by Kant as those phenomena perceived by our consciousness that comply with an innate set of logical rules named "transcendental logic." Phenomena not complying with these rules are discarded by our consciousness as illusions.

Moreover, Kant believed that prior to this conscious "censorship" there is a pre-conscious manipulation of the raw sensory input, before it arrives at our consciousness, which adapts it to the laws of the transcendental logic, so that sensory impressions can be accepted as experience. Kant named this pre-con-

Requests for reprints should be sent to Uri Fidelman, Ph.D., Department Humanities and Arts, Technion, Israel Institute of Technology, Haifa 32000, Israel. Email: uf@tx.technion.ac.il

scious manipulative mechanism "creative imagination" and concluded that we cannot know anything with absolute certainty about the things as they are in themselves.

Modern experimental cognitive psychology arrived at a conclusion similar to that of Kant. Treisman and Schmidt (1982) found that preattentive visual data undergo a process of biological censorship that adapts them to logic before arriving at our consciousness. Here we shall survey the reasons for this claim and the biological mechanisms underlying this second censorship.

We will see that the existence of this biological censorship explains the fact that the duality of wave versus object (particle), which dominates the microscopic world, has no role in the macroscopic world: this censorship causes us to perceive each object as having the same physical features whenever we perceive it (it does not change its features when we reinitiate our visual perception, say, due to movements of our eyes). Thus we avoid possible ambiguity in our perception of the macroscopic physical world, which might have caused us to see a macroscopic object as a probabilistic superposition of more than one object, each of them having different features, which is describable by Schoedinger's quantum mechanical equation as a probabilistic wave, rather than by Newton's classical physics. The models by which we perceive and cognize the physical world are created by a biological mechanism, the CNS: it appears that physics may be created by biology.

Visual Search

In visual search method of cognitive psychology several items are presented to the subject simultaneously. One of these items is a target, known in advance to the subject, the other items are distractors. The subject is asked whether the target is one of the presented items. The dependent variables are the correctness of the answers and the reaction times. The relation between the correctness of the answer, the reaction time, and the number of the features of the target and of the distractors is analyzed in order to suggest a model explaining our visual perception. There are several such models. One of the most important is the guided search model of Wolfe (1994).

According to this model the visual perception during visual search includes two stages. The first stage is preattentive. At this stage the features of the presented items, or objects, are organized as "feature maps." In these maps each feature is represented separately in an area of the visual cerebral cortex in a retinotopic organization. Each feature is represented on a separate "page" of the "atlas" (book of maps). The initial intensity of the representation of a feature of an item on the "page" related to this feature is determined by the intensity of the sensory activation of the retinal location activated by an item having this feature (bottom-up activation). In addition the CNS strengthens the intensity of the representations of all the features of the target. The activation of each cortical area that serves as a "page" of the "atlas" on which all the locations of a feature of the target are represented increases, due to top-down activation by the CNS.

After the creation of the feature maps, a superposition of all of them is created, called the "activation map." That is, the activation intensity of the neurons representing all the features of all the items in the feature maps are summed and the sum is represented in the activation map at the retinotopic location of the related features. Thus the activation map represents all the perceived objects at their retinotopic location. The strengthening of the intensity of the features of the target by the CNS's top-down activation causes the representation of the target to be one of the strongest in the activation map. This terminates the first stage of the visual search.

The second stage of visual search is attentive. At this stage attention moves from one item to another serially, according to the order of the magnitude of the strength of the neural representation of the object in the activation map. That is, the items having the strongest representations in the activation map are the first to be scanned during the second stage. Since the representation of the target is strengthened by the CNS, the target is the first or the second item that is scanned. This observation explains the high efficiency of visual search. The object exists in our consciousness only since the moment in which it comes to the focus of attention. At this moment the object integration occurs, which is the conjunction of all the features of the item into an object (that is, an "object" is defined as the conjunction, or joining together, of all its features at a certain location). Before this object integration we are not aware of the existence of the object.

The guided search model is related to existing biological structures, the hemispheric mechanisms. Therefore this model is not a reification, but it has a physiological basis. This physiological basis of the guided search model may be applied to explain the existence of two ontological approaches, Platonism and nominalism. According to Platonism only features (each feature represents the totality of the objects having this feature) exist, while according to nominalism only individual objects exist. Fidelman (1995, 1999) suggested and referred to evidence that the preattentive perception of features is performed by the holistic neural mechanism that is related to the right hemisphere, while the attentive stage of visual search (in which the object integration occurs) is performed by the serial mechanism related to the left hemisphere. The evidence referred to and interpreted by Fidelman (1999) includes experiments with PET imaging and electrical activity of the brain, as well as evidence from Posner and Raichle (1994). It may be that the right hemisphere, which perceives wholes simultaneously (Ben Dov and Carmon, 1976) and processes the features in the preattentive stage of the guided search model, also performs the perception of features and the cognition of the world according to Platonic ontology, which is related to wholistic features.

On the other hand, the left hemisphere that analyses individual items one after another serially (Ben Dov and Carmon, 1976), perceives individual objects one after another temporally and cognizes the world according to the nominalist ontology. The cognitive conflict between these two views is, in fact, a conflict between two neural mechanisms that perceive the same physical world in two ontologically different modes. Indeed, the Kantian modes of perception, space and time, are related to the right and left hemispheric mechanisms, respectively, as do the Platonic and nominalist ontologies, respectively. This analogy justifies calling these ontologies "ontological modes of perception."

Illusory Conjunction

According to Treisman and Schmidt (1982) the features of items are not localized before object integration, that is, preattentional feature maps are neural but not cognitive. This view is based on the following experimental evidence. Subjects of visual search experiments often report that they see some feature, for example, the color red, but are unable to report what is the red object and its location. Moreover, when two objects are presented to a subject, for example, a green umbrella and a yellow ball, the subject sometimes reports seeing a yellow umbrella and a green ball. This phenomenon is called "illusory conjunction" (of the features).

In another experiment described by Treisman and Schmidt several slides of colored photographs from magazines were briefly presented to subjects, who were requested to report what they saw. Some of the subjects swapped the colors of the presented objects. For example, some subjects reported seeing a photograph of a red headed woman, wearing a black blouse, while on the slide was a photograph of a black haired woman wearing a red blouse. The subjects reported seeing the interchanged colors as confidently as seeing clear physical objects, and not as guesses, for example, following the lack of clear information due to the short time of presentation. Treisman and Schmidt related this phenomenon of illusory conjunction to the brief time of inspection which, according to their suggestion, caused a burden on the attention of the subjects, resulting in mistakes in the integration of the objects as a conjunction of their features.

However, we should notice that due to the saccadic movements of our eyes their fixation on a certain point is very short, usually less than a second (these eye movements evolved in order to avoid the termination of visual perception due to the running out of rhodopsin in the area of the retina where the vision is focused, and to enable the renewal of its supply). Therefore, in normal vision, as well as in brief exposure of slides, we have the same kind of burden on attention. This implies that we may expect to encounter illusory conjunction even during normal visual perception.

In these two examples the colors of two objects were interchanged. "Color" is an example of "dimension," which is defined in cognitive psychology of vision as a feature common to several features, like red, blue, green, etc., all share the common feature of being a color. Other examples of dimensions are shape, size and inclination. An exchange of features between two objects presented simultaneously in the visual field, as a result of illusory conjunction, can occur only when these feature have the same dimension.

The observation that the features are not localized before the object-integration makes their migration between objects possible. There are several possible conjunctions of features, that are presented simultaneously in the visual field, into an object. Therefore the occurring conjunction of features is not determined in advance. Thus illusory conjunctions may occur at random. However, according to Treisman and Schmidt (1982) there is a control mechanism, of which we are unaware, that prevents most of the random illusory conjunctions from arriving at our consciousness. This mechanism selects among the several possible conjunctions of features those that are recognizable by the subject from previous experience, and seem to be most reasonable. Thus most of the random conjunctions are discarded as non-rational by the pre-conscious control mechanism.

For example, our experience is that the color of the sky is, usually, blue or gray, and the color of grass is green. Similarly, people have noses and tables have not. Since we expect that the usual is what we see, conjunction of features resulting in green sky and blue grass, or flat faces and tables with noses, is rejected by our cerebral mechanism that selects logical conjunctions among the possible. That is, when our expectations are identical with the data obtained by our senses, illusory conjunctions do not occur.

But sometimes our expectations regarding the input that our senses will obtain from the physical world are wrong. Treisman and Schmidt (1982) provide the following example. A person passes in a crowded street (that is, attention is loaded) and expects to meet an acquaintance having the following features: black beard, glasses and bald head. The person sees this acquaintance and wants to address him. Then the person notices that the black beard belongs to a man that passes by, and the bald head and the glasses belong to another one. The expectation to see an object may cause a subject to see an object that is not there, provided that the presence of this object seems to the subject as expected and logical.

The operation of this control mechanism is based on learning. A newly born baby does not perceive anything visually. Only repeated experience causes the development of cells in the visual cortex that react to specific features of the observed objects: color, shape, inclination, etc. This development is due to the fact that new dendritic branches are growing and creating new synapses all the time. If a new synapse is applied repeatedly by the brain it becomes stronger and permanent, otherwise it disappears. Thus neural paths representing objects that are perceived repeatedly are created. The more these paths are applied the stronger become the synapses and the neural axons along these paths (this is the mechanism of learning). Therefore paths in our visual cortex that represent familiar objects have advantage while they compete with paths that represent non familiar objects that may be integrated due to illusory conjunction. The more familiar an integrated object is, the stronger are the synapses in the neural path representing it, and the larger is the probability that messages representing this object will pass through its path without transmission errors, and will be the first to be accepted by our consciousness. This advantage may be the basis of Treisman's censorship, and its probabilistic nature (due to the probabilistic nature of the synaptic transmission errors) may be the reason for the existence of illusory conjunctions that arrive at our consciousness.

In conclusion, Treisman and Schmidt probably were not aware of the relation between their work and Kant's theory of consciousness. Nevertheless, their findings are in line with Kant's hypothesis that our sensory input is corrected by the creative imagination, which is the logic acting at a pre-conscious stage. The creative imagination rejects non-logical phenomena as illusions, but it may also accept illusions as experience if they are logical. Therefore the perception of the world that arrives at our consciousness does not necessarily represent the outer physical world faithfully. This perceived image of the word represents the physical phenomena under a limitation of probabilistic uncertainty, which is in line with the probabilistic nature of quantum physics.

It is reasonable that the evolution of censorship occurred together with the evolution of consciousness. Censorship compels us to perceive events having very high probability of occurrence as certainties, and events having very low probability of occurrence as not occurring. The advantage of the censorship of perception is that it prevents contradictions in the perceived world and makes possible the evolution of conventional logic applicable for the macroscopic physical world. Logic has an evolutionary advantage, since it enables us to plan our future actions, with a very low probability of errors (because our perception has high probability of being valid). Thus logic contributes to our struggle for survival.

The Microscopic World

The probabilistic image of the macroscopic world, obtained from the existence of illusory conjunctions, does not suit the image of the world according to classical physics. However, it suits the image of the microscopic world according to quantum mechanics (Fidelman, 2002, 2004a, 2004b, in press; Peruš, 2001, in press).

Our knowledge about the microscopic world, e.g., about particles like electrons, is not obtained directly as sensory input. It is interpretation of data obtained by scientific instruments. Our senses perceive readings of scientific instruments, which are macroscopic phenomena. The perceptual "censorship" of Kant and Treisman has no reason to discard these readings of the instruments at the perceptual stage. However, when these readings are analyzed later, they are interpreted as indicating the existence of a probabilistic microscopic world, which does not comply with transcendental logic, but behaves like the macroscopic world before its manipulation by censorship.

We observe that the physics of the microscopic world includes representations of the two ontological aspects of the macroscopic world. The unlocalized Platonic features of the preattentional stage of visual search are represented by unlocalized waves. For example, the cognitive feature "red" is analogous to an unlocalized wave with a wave-length of 6500Å. But "red" can be associated also with a localized nominalist object, called "photon," which is analogous to the objects integrated at the attentive stage of visual search. Indeed, this is the duality in physics: according to quantum mechanics each physical entity can be conceived as both a particle and a wave.

Now we ask: Why is the uncensored picture of the macroscopic world similar to the interpretation that suits the registrations of our instruments, which represent data from the microscopic world? In order to answer this question we should notice that neither the wave, nor the particle versions of our cognizing the microscopic world are perceived by our senses, both are imagined. Imaging is performed by the CNS applying a top-down activation of the extra striate visual cortex, in a process called reentrant (Posner and Raichle 1994, see chapter 4, pp. 144–145, 242–243). The neural mechanism that receives the sensory input is activated while the subject imagines a picture instead of actually seeing it. We may conclude that the same neural mechanism that processes the sensory data obtained from the macroscopic outer world into features and objects performs also the imaging of the microscopic world. Therefore the microscopic world too is imagined as un-localized features (waves) and as localized objects (particles).

Collapse of the Wave Function

According to the guided search model, when attention is focused at a certain location, the object located there is integrated from its features that are presented in the features maps. Before this integration, the features are not localized and at each location there is no definite object, but a probabilistic superposition of all the possible combinations of features. A similar situation occurs also in the physics of the microscopic world.

Before a measurement or a detection of a particle at a location occurs, this particle does not exist. Instead, there is a non-localized superposition of the features of all the particles that may be present at this location, or of all the possible locations of the particle, which is presented mathematically by Schroedinger's equation as a wave. As soon as a measurement or a detection of a microscopic phenomenon by instruments occurs, the wave function collapses. That is, only one of the possible conjunction of features, or one of the possible locations that are represented in the superposition are registered by the instrument, and instead of interpreting the registrations of the instruments as representing an unlocalized wave, we interpret them as representing a localized particle.

It may then follow that our cognitive models of both the macroscopic and microscopic world are performed by the same neural mechanisms, which account for the similarity of these models. Both the object integration in the macroscopic world and the collapse of the wave function in the microscopic world are the replacing of the cognitive model created by the right cerebral hemisphere by a cognitive model created by the left cerebral hemisphere. This dependence of our current model of the physical world on the neural hemispheric mechanism applied at the relevant moment implies doubt about the objectivity of this model and in our knowledge of what really is "out there." This leads us to Kant's view that we cannot know anything certainly about things as they are in themselves.

Discussion

Both philosophy and psychology have a biological basis: the existence of two ontological approaches is related to the existence of two different hemispheric mechanisms. This view is in line with experimental findings (Fidelman, 1989, 1990), in which students who studied ontology of mathematics and physics were asked to choose between philosophical schools that have different ontological views. The students were tested using tests that measured their hemispheric efficiency. It was found that students who preferred a nominalist school over a Platonist school had a left hemisphere more efficient than their right one, and students who preferred a Platonist school over a nominalist one had a right hemisphere more efficient than their left.

We observed that Kant predicted phenomena that were discovered by Treisman hundreds of years later. The intuition of philosophers may guide biological psychologists in choosing subjects for research. On the other hand, research in biological psychology may support or falsify philosophical theory. The relation between philosophy and cognitive biological psychology may be analogous to the relation between theoretical science and experimental science (Fidelman, 1991). Moreover, applying the three disciplines: biological psychology, philosophy, and physics provides a deep insight into the nature of ontology (left- versus right-hemisphere, nominalism versus Platonism, particle versus wave, respectively). The same is true regarding the relation between Treisman's censorship, Kant's creative imagination and quantum mechanics (discarding illusory conjunctions, discarding illogical phenomena, the materialization of only one of several entangled particles, respectively). The conclusions of the three disciplines clarify and strengthen each other.

The outcome of this study is approved and extended by the findings of Peruš (2001, in press). He used the technique of mathematical analysis of neural networks (including a mathematical model of psychological principles, like Hebb's theory of learning and memory) and applied quantum mechanics to this model and obtained findings, that are, in fact, identical to the findings of this study and of Fidelman (2002, 2004b). Perus concludes that the collapse of the wave function occurs within the brain's neural network. This collapse is a transition from non-conscious processing of perceptual data by the brain to conscious processing. Peruš's non-conscious processing is, in our framework, the preattentional processing of features, and his conscious processing following the collapse of the wave function is our attentional processing of visual data. Thus we may consider the mathematical work of Peruš to be a theoretical prediction of the relation of Treisman's empirical findings to quantum mechanics, and we may consider the empirical work of Treisman to be a partial experimental verification of the theory of Peruš. We may conclude that the works of Peruš and of Treisman support and add credibility to each other.

The work of Treisman is not universally accepted, and there are competing theories that do not recognize the role of illusory conjunction or that disagree about other details of her theory (see, e.g., Duncan and Humphreys, 1989, 1992; Wolfe, 1994). Nevertheless, even the researchers who disagree with details of Treisman's work were influenced by her and adopted large parts of her ideas. Thus the essentials of Treisman's theory form part of many of the competing theories. In this study we have obtained three arguments favoring essentials of the theory of Treisman:

1. It suits the above described theory of learning, according to which the past repeated perceptions of an acquainted object give it an advantage while competing with a non-acquainted illusory conjunction (like a table that has a nose).
2. Microscopic quantum entities are entangled features, which are presented by Schroedinger's equation. Nevertheless, when the locations or the features of the quantum entities are detected or measured by instruments, the data enable us to imagine the quantum entity as a particle, which is imagined as a tiny macroscopic body. This imagining is the collapse of the wave function. It is performed by the mechanism of ordinary perception of macroscopic bodies, when top-down activation of the presented features replaces their bottom-up activation by visual perceptual input. This means that when the same mechanism perceives macroscopic objects it may be able to operate in the same mode, and the object integration too may be a collapse of the wave function. Treisman's theory may explain both macroscopic perception and microscopic imagining.
3. The mathematical model of Perus suits the theory of Treisman, in particular the changing of data processing from non-conscious (preattentional) to conscious (attentional) at the moment of object integration. Thus, in conclusion, we have reasons to accept the essentials of Treisman's theory. These reasons are independent of the discussion about details among the experts of visual search. These reasons concern the deep relationship between the neural mechanism of visual perception and quantum mechanics.

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