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Multimodal conceptualization of consciousness in motor control

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All truth passes through three stages.
First, it is ridiculed.
Second, it is violently opposed.
Third, it is accepted as being self-evident.

Arthur Schopenhauer

The authors examine the issue of consciousness from a systemic-theoretical perspective, not based on experimental research. They argue that psychological problems are so distant – in intellectual terms – from reality that tracing the relations between observable, experimentally measurable phenomena and internal processes in mind seems to be almost impossible. Moreover, the whole system of information processing in humans – including consciousness – is of multimodal nature, which makes all analyses rather difficult. As a result, it appears impossible to assign unambiguously psychological processes to observable phenomena. Thus, the authors propose to apply a mental technique termed "interpretation of the best explanation" based on the five-level construction of movement theory by N.A. Bernstein (systemic, in fact) and a less detailed motor theory of language by R. Allott. They propose the definition of the term "consciousness" and show its place in the whole chain of events determining human behavior. By using Bernstein's theory, they define the terms "real consciousness", "virtual consciousness", "potential consciousness" and "active consciousness", coherent with the theory of attention by R.M. Nideffer. They compare the issues under consideration with problems of physics and draw a conclusion that the questions of mechanisms determining animal and human behavior – the only observable manifestation of which is a movement – are probably most challenging to the whole contemporary science.

KEY WORDS: consciousness, human cognition, human behavior, cognitive science, neuroscience.

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What is already known on this topic?
An exhaustive review paper on the concept of consciousness was published by Melanie Boly et al. [1]. The main problem is that this issue is currently being investigated experimentally, though it is hardly liable to such kind of research, and it needs, above all, theoretical conceptualizations. Unfortunately, the share of theoretical speculations in this respect seems to be far too low, and even the best "new and original experimental data" cannot build this fragment of psychology by itself.

Introduction

The inspiration for writing this paper was a thorough and exhaustive paper by Melanie Boly and her colleagues on consciousness in humans and animals [1]. The leitmotif determining the course of analysis in the present study are the words by physicist and Nobel prize winner, Richard P. Feynman:

> *This is the key of modern science and it was the beginning of the true understanding of Nature – this idea to look at the thing, to record the details, and to hope that in the information thus obtained might lie a clue to* ***one or another*** *theoretical interpretation* (emphasis ours, WP & MS) [2].

Highly instructive seem also the following statements by psychologist and motor control specialist Richard A. Schmidt, and mathematician and philosopher Józef Życiński that, in fact, express the same idea:

> *Since laws are the product of human creativity, different laws can be formulated by two different individuals who are examining the same observations. Laws do not automatically spring forth from the facts (unlike the image on a piece of exposed film that emerges from the colors of separate molecules of pigment on it) (…)* [3].
>
> *(…) the same reality may be described correctly with different theories though to various degrees of precision* [4].

All these ideas are illustrated by Fig. 1.

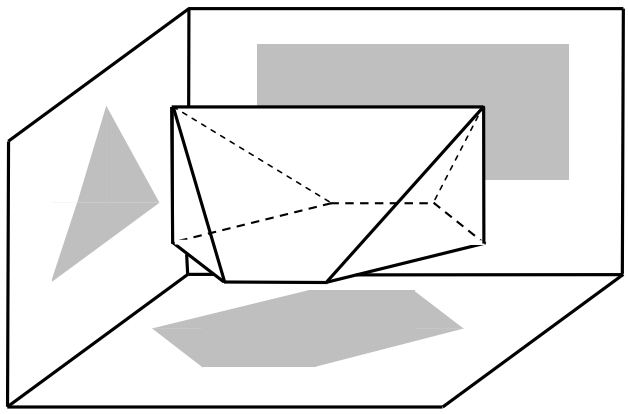

Figure 1. Different views of reality when seen from various perspectives

Figure 1 shows a shape casting three shadows onto three different planes. All the shadows come from the same body: one neither truer nor falser than the other. Each of them, however, differs significantly from the other two. Analogously, the main goal of this article is not to question the ideas presented by Melanie Boly et al. [1], but to dispute with them and to show the issue of consciousness from a slightly different perspective. The "starting point" of reasoning in this paper can be the following statement by mathematician René Thom:

> *Since the 17th century modern science has been possible only as much as theoretical progress overtakes the experiment. We owe great achievements no more to discovery of new facts, but they appear rather as new ways of thinking or interpretations of already known facts* [5].

Following this idea, we would like to present a slightly different "shadow" of the item termed "consciousness" than descriptions found in popular psychological books and articles.

1. The most primeval roots of consciousness

The problem of consciousness constitutes the very basis all activities of all living creatures. In 1881 Charles Darwin wrote:

> *If worms have the power of acquiring some notion, however rude, of the shape of an object and over their burrows, as seems to be the case, they deserve to be called intelligent; for they act in nearly the same manner as would man under similar circumstances* [6].

In 1906 Herbert S. Jennings remarked:

> *I believe it beyond question that we should find similar attribution to it of certain states of consciousness a practical assistance in foreseeing and controlling its behavior. An amoeba is a beast of prey and gives the impression of being controlled by the same elemental impulses as higher beasts of prey* [7].

In 1915 Edward Heron-Allen concluded:

> *When we arrive at the consideration of the arenaceous form it behooves us to proceed with the greatest possible caution, for the phenomena exhibited reveal an apparent development of purpose and what in the Metazoa would be termed "intelligence", which is apt to lead the imagination far astray unless it is kept rigidly within the bounds imposed by observed results (…)* [8].

Thus since Heron-Allen discovered intelligent behavior in the single-cellular *Foraminifera*, there is no reason for speculation that humans make an exceptional species in this respect. Moreover, intelligence has to be rooted in some kind of consciousness, thus – while looking at those issues through "system-theoretical glasses" – *Foraminifera* have to possess some specific kind of consciousness. However, it has to be consciousness of another informational modality than that in humans.

Consequently, there have to exist various modalities of consciousness. Those typical for animals are based on sensory experiences. Unfortunately, the close relation

of information processing with sensory experiences limits the temporal extension of controlled phenomena to *timing.* Arturo Hotz described it as follows:

> *Timing is the temporal punctuality towards a spatial point, and also the functional potential to be at a proper time, with an optimum speed and in a relevant place* [9].

To extend the temporal scale beyond these limits, it was necessary to detach information processing from current stimuli. An information carrier immune to time lapse is the word. According to Robin Allott's motor theory of language:

> *The semantic, syntactic and phonetic structures of language developed on the basis of a complex pre-existing system. More specifically, the structures of language were a transfer from or a calque of the structures of the pre-existing motor system"* [10].

Hence, the consciousness and information processing may be based both on sensory experiences and on fully abstract words or symbols.

2. Consciousness as a phenomenon

While following the logical advice by Alan Sokal and Jean Bricmont that "*It is a good idea to know what one is talking about*", it seems reasonable to provide a description of the term "consciousness", even if only tentative. Here highly instructive may be words by Niels Bohr, who dealt with physics, i.e. much simpler matter than that of psychology and motor control. Bohr stated that:

> *It is wrong to think that the task of physics is to find out how Nature is; physics is concerned with what we say about Nature* (emphasis ours – WP & MS).

Accordingly, let us define consciousness as follows:

> ***Consciousness*** *– «the internal diagnostic tool of a living being that enables abstract representations in observer's mind of the current state of the environment, mutual interactions between its components as well as the relations between the observer and the environment, based on actual sensory experiences and information retrieved from one's own memory».*

Two main attributes of consciousness that result from this definition can be distinguished:

1. Current contact with the environment and/or one's own memory.
2. Knowledge about the net of relations between the observer and the environment.

The former needs either sensory contact with the environment (A, B and C-levels), or with its direct real representation in one's own memory (D-level), and thus may be termed **real consciousness**. The latter results from one's own knowledge about the world that is detached from direct contact with reality. It "resides" mainly in abstract memory (D and E levels) and may be termed **virtual consciousness**.

In short, one may state that perception consists of joining either sensory inputs produced by sensory organs when excited by physical stimuli, or engrams from one's own memory with a specific knowledge. In this way percepts are being produced. It must be emphasized that percepts are of discrete and not continuous nature. In our conceptualization the discretization of information that determines the "digital way" of functioning of the central nervous system (CNS) starts already in the process of perception. This assumption differs slightly from the idea by William James [11], but the general idea of discrete information processing remains the same.

Thus identified, the percepts are bound together into systems mirroring the reality in the abstract sphere of mind. This way consciousness is being born. According to William James:

> *The intellectual life of man consists almost wholly in his substitution of a conceptual order for the perceptual order in which his experience originally comes* [11].

Summing up, consciousness is that part of the whole knowledge of an individual which is currently activated either by extrinsic stimuli or by intrinsic engrams. If accepting such a definition as right, consciousness is an ordered system of percepts and makes a "raw material" for intellect (instinct, intuition and intelligence). However, according to the premise of scales' conformity, consciousness at each level has to communicate with a respective kind of intellect using one's own information processing modality. To put it shortly and illustratively, one kind of intellect, which results from a consciousness modality, is needed for a theoretical physicist and another for a pilot of a supersonic jet fighter.

Thus, consciousness is of multilevel and multifaceted nature. It bridges the gap between the already possessed knowledge and current information rooted in the environment and acquired by means of one's own senses ("*current state of the environment*"). This model enables creation of a different "shadow" of consciousness

(Fig. 1) than the one commonly known. The whole body of knowledge may be termed **potential consciousness**. It may be – roughly – divided into "working" **active consciousness** and "dozing" **inactive consciousness**. The latter includes all the knowledge "sleeping" in memory, but ready to use when needed. Its confrontation with current sensory experiences or respective engrams, i.e. attention, makes it active. Hence, the boundaries between active and inactive consciousness change dynamically during any mental-motor activity. Here, highly illustrative may be the "spotlight metaphor" by Nikolai A. Bernstein, who wrote that:

> *(…) for each human movement, whether complex or simple, full of deep meaning or feasible for any frog, consciousness obtains only information relevant to what is being managed by the leading level. This is how our consciousness is built. Its spotlight, as a rule, cannot illuminate more than one level at a time, although it is able to illuminate them successively* [12, 13].

The spotlight in this metaphor may be identified with attention, and the limited scope of items illuminated by it with the "magical number 7 ± 2" by George A. Miller [14]. He was one of the first western scientists who dared to look into the behavioristic "black box" and made a remarkable contribution to putting the behavioristic paradigm in science out to pasture.

By the way, the perspective assumed in this paper, which led to the coining of the original terms "real consciousness", "virtual consciousness", "potential consciousness", "active consciousness" and "inactive consciousness" remains in accordance with the theory of attention by Robert M. Nideffer [15]. His external attention may be associated with real consciousness; internal attention – with virtual consciousness; narrow and wide attention – with the range of active consciousness (either real, or virtual) at a given moment. Moreover, in the model proposed in this paper, the border between brightness and darkness is not sharp, but it may make a quite fuzzy zone of twilight. In other words, between "active consciousness" (brightness) and "inactive consciousness" (darkness) there is a "half-active consciousness" (twilight) that may be associated with what is commonly termed "sub-consciousness". The knowledge "residing" in that region is not as ready to use as that from "active consciousness", but its possible evoking is much easier than that from "inactive consciousness" (thus it may be compared to a specific "mental priming"). It is worth noticing, too, that Sigmund Freud, whose name is often associated with this term, did not like it and preferred using the term "fore-consciousness" [16]. Thus, elimination of this term – the meaning of which is very unclear – may probably contribute to a simplification of terminology, and, consequently, to a better comprehension of the issues under consideration.

3. Various modalities of consciousness

The considerations in this paper focus on the way of thinking – systemic in its core – developed by neurophysiologist Nikolai Aleksandrovich Bernstein. He wrote his papers nearly exclusively in Russian, thus, in the West, only some of them (mainly those few translated into English) are known. His name is usually associated with the problem of degrees of freedom in motor control, though, in fact, it was his minor achievement. Bernstein's most significant attainment was the five-level movement construction system [17, 12]. It was described in English no sooner than in 1996, i.e. 30 years after Bernstein's death [13]. By the way, although a full presentation of the theory of systems was given by L. von Bertalanffy only in 1968 (i.e. two years after Bernstein's death), the much earlier theory by Bernstein is fully coherent with that by von Bertalanffy [18].

Bernstein followed the evolutionary development of sense organs, the nervous system, and information processing abilities based on it. Next, he analyzed the motor potentialities of living beings, especially vertebrates, determined by the development of both the nervous system (senses and brain) and working organs. He discerned five levels of movement construction, tightly joined with specific structures in the central nervous system:

- A-level, rubro-spinal, responsible for muscle tonus;
- B-level, thalamo-pallidal, responsible for muscle synergies;
- C-level, cortical, pyramidal and striatal, responsible for movements in space;
- D-level, cortical, parietal-premotor, responsible for abstract representations of real motor operations;
- E-level, cortical; Bernstein described it as "*lying over operation level **group** E*" (emphasis ours – WP & MS) [17].

A representation of Bernstein's five-level movement construction system is shown in Figure 2 [19]. It only mirrors the general idea of Bernstein's theory, as he never represented it graphically himself.

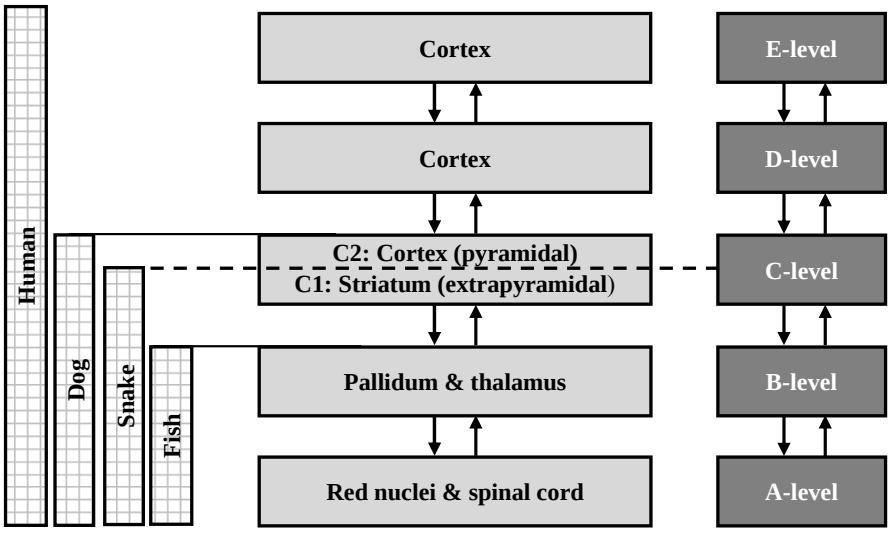

Figure 2. The system of motor control levels according to N.A. Bernstein

Though Melanie Boly and associates do not refer to studies on the systemic structure of whole information processing in humans, such as those by John Hughlings-Jackson, Nikolai Aleksandovich Bernstein, Paul D. MacLean, or Arthur Vander, the idea of such a structure may be traced in the following statement:

> *Recent EEG (electroencephalography) studies also provide some evidence that, again similar to what is found in the VS (vegetative state), general anesthesia might be characterized by stereotypical responses to transcranial magnetic stimulation (TMS) (…) and disruption of* ***"top-down" functional connectivity from frontal to sensory areas*** *(emphasis ours – WP & MS)* [1].

The solid neuro-physiological and evolutionary foundations of Bernstein's theory have some probability that the reasoning based on it may not be false. Bernstein's theory, therefore, makes only a "starting point" for considerations in this paper. We continue his way of reasoning and not merely reproduce what he wrote more than half a century ago [20].

In the course of evolution, as a result of encephalization, the newly formed levels took over the tasks previously performed by the lower ones, and, on the other hand, they endowed lower levels with new abilities. As a result, the connections of particular classes of motor operations and respective structures in the CNS became "fuzzy". In this context analyses of motor operations, especially in humans, are extremely difficult. In particular, it seems that by now there are no mathematical tools enabling description of those issues [5, 21, 22, 23]. It seems thus reasonable to build, on the basis of Bernstein's theory, a simplified – and, thanks to that – graspable, functional model focusing on information processing modalities. Accordingly, one may take an information processing modality (including both a specific code and information processing methodology) as a criterion determining what may be regarded as Bernstein's level of "identity" and develop the following "ladder of modalities":

- A-level – intrinsic stimuli, motor couplings, reflexes;
- B-level – contact stimuli, motor stereotypes, automatisms;
- C-level – remote stimuli, motor scenarios, habits;
- D-level – verbal code, motor programs, performance;
- E-level – symbolic code, motor vision, no real motor operation.

Such differentiation of information processing modalities assigned to particular levels corresponds with the premise of scales conformity developed by Janusz M. Morawski [24]. As a result, the systems theory and Bernstein's theory turn out to be fully coherent. All the more, it is coherent with the concept of five-level self-awareness by Philippe Rochat [25].

It is worth noticing that a reflex may be associated with "*unconditioned reflex*" by Ivan P. Pavlov, and automatism with "*conditioned reflex*". However, the "classical" terminology seems to be somewhat misleading. It suggests that "*unconditioned reflex*" and "*conditioned reflex*" are two varieties of the same phenomenon (*reflex*). This is not right since each of them is controlled from different floors of the CNS, has its own specific attributes (the former is hardly shapeable, the latter has to be shaped), and, eventually, each plays a different function in the whole structure of human motor activities. Hence, in this paper the terms "reflex" and "automatism" are used instead of "unconditioned reflex" and "conditioned reflex", respectively. It should be noted that the two traditional terms are used very rarely in contemporary scientific literature.

We must remember that in such an approach all the information processing mechanisms in animals and humans make one coherent, yet not a homogenous system. Moreover, the only observable result of the whole internal information processing is the movement, even if only that, of the jaws and the tongue.

Here one may refer to the title of the paper by Melanie Boly and her colleagues: "*Consciousness in **humans** and non-human **animals***" [1]. In general, animals have fully developed only the A, B and C levels, whereas humans – the D and E levels as well. As a result, humans are able to use information processing techniques specific to the D and E levels as well as knowledge and skills specific to the A, B and C levels. Probably, it is thanks to this that many animals are stronger and faster than humans, but it is, nevertheless, *Homo sapiens* that takes place on the apex of the pyramid of living beings on Earth.

It is worth noticing that the development of D and E levels in humans did not "switch off" the potentialities of the lower ones. In his paper on muscle tension in elite and novice basketball players Paweł Pakosz established on the basis of EMG measurements that along with experience accumulation the muscle tension unengaged during a basketball throw decreased [26]. This contributes to general exercise economy, without any diminishment of effectiveness; on the contrary, such a process combines energy saving and effectiveness increase thus improving efficiency. These relatively stable changes need information processing, and consciousness makes a necessary basis for it. The problem is what modality is used in "proprioceptive consciousness" that underlies muscle relaxation and tension. However, in order to consider it, one must accept the premise that human consciousness is of multimodal nature. Moreover, the particular levels, using various modalities, cooperate with each other in a systemic way, though, for example, it is not possible to "translate" directly the verbal modality into the proprioceptive one. For instance, it is not possible to explain verbally, how fast one has to grip an egg to neither let it fall, nor crush it. Nevertheless, the proprioceptive, contactceptive, teleceptive, verbal and symbolic information processing in humans (specific to A, B, C, D and E levels, respectively) makes up one coherent, though not homogenous, system of information processing that includes both consciousness and current motor operation control.

4. Consciousness as an object of scientific research

By applying an evolutionary perspective, one may assume that the phenomenon termed "consciousness" had been created along with the evolutionary development of living creatures. However, this creation was not "smooth" and gradual but happened in several clearly discernible steps. Nevertheless, one may try to follow the development of consciousness in the course of evolution, but here arises the problem of methodology of such investigations. In this respect very instructive seem to be the words by Albert Einstein, Richard Dawkins and Gilbert H. Harman, who stated that:

> *Physics constitutes a logical system of thought which is in a state of evolution, whose basis cannot be distilled, as it were, from experience by an inductive method, but can only be arrived at by free invention* [27].
>
> *Careful inference can be more reliable than "actual observation", however strongly our intuition protests at admitting it* [28].
>
> *In making this inference* (inference to the best explanation – WP & MS) *one infers, from the fact that a certain hypothesis would explain the evidence, to the truth of that hypothesis. In general, there will be several hypotheses which might explain the evidence, so one must be able to reject all such alternative hypotheses before one is warranted in making the inference. Thus one infers, from the premise that a given hypothesis would provide a "better" explanation for the evidence than would another hypothesis to the conclusion that a given hypothesis is true* [29].

One might say, therefore, that observations and experimental data make knowledge indeed, but free invention and careful inference are absolutely necessary to transform random knowledge into a systematically ordered science. All the more, conceptualization, inference and intuition seem to be especially important in disciplines which are hardly liable to experimental research, e.g. motor control.

However, one comes here across a specific "fashion" in science. In physics, the relation between a stimulus and a reaction is quite simple and easily describable with the use of mathematics. On the other hand, in biology, one has to do with a much longer cause and effect chain, consisting of a stimulus – information (which has to be identified, assessed and processed) – and only then a response (but no longer a sheer reaction!). Such a chain is hardly describable with mathematics, and thus research methods which are highly effective in, for example, physics are not so efficacious in motor

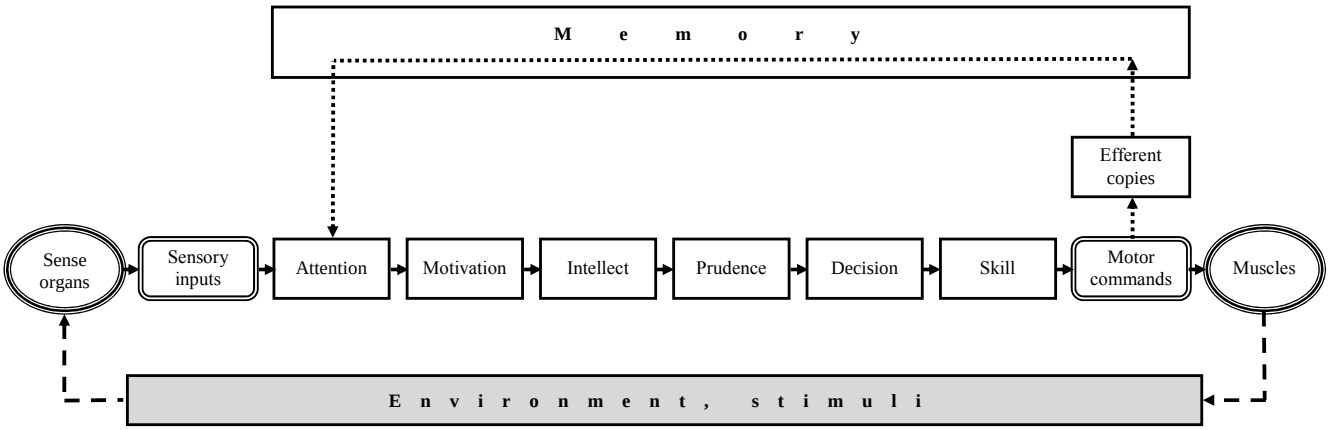

Figure 3. General (simplified) flow of information during a motor operation without division according to the "ladder of modalities". Rectangular blocks – psychology; blocks with rounded edges – neurophysiology; oval blocks – physiology; gray shaded block – physics. Clearly visible are two loops of information processing: one including memory (higher, dotted line) and the other including reaction to the environment and stimuli (lower, broken line)

control. Summing up, unlike in physics, in motor control the arithmetic mean, standard deviation and even correlation coefficient are not as meaningful as in physics. Unfortunately, despite this, many scientists fascinated with their research devices try again and again to adopt purely experimental methods to investigate phenomena and processes which need not experiments but "careful inference" to be explained.

It seems almost impossible to consider the problems of consciousness apart from its function in the shaping of the whole human behavior. Moreover, the only phenomenon that enables us to hypothesize about what happens in mind is movement. Therefore, let us present – from the system-theoretical perspective – the entire cause-effect chain leading to the production of movement.

5. Consciousness as a link in the information processing chain in movement control

The process underlying a final behavior starts with an engram retrieved from one's own memory, either after reception of an extrinsic stimulus (reception, reactive mode), or independently of it (remembering, active mode). The latter is based on anticipation and enables preparation of an action before an essential stimulus appears (or avoiding undesirable stimuli).

Next, comes **perception**, i.e. joining an engram with information specific to it. Here another important process occurs, i.e. chunking. The stream of stimuli and sensory inputs is, roughly, continuous, but the identified information is of discrete nature (consisting of chunks). Assuming a constructivist perspective, information identification consists of association of received sensory input with specific knowledge that resides in one's own memory.

The product of perception is **consciousness**, i.e. portion of the whole knowledge of an individual activated by **attention**. It makes the basis for the other task of attention, i.e. assigning specific importance to particular chunks of information and thus creating a specific hierarchy of information. Only the most important chunks of information are then passed for further processing. Just the set of chunks assessed as being most important determines the direction of later information processing. It seems worth emphasizing that in the system-theoretical approach not only motivation, but also attention determines the direction of further thinking.

The next link in the chain is **motivation** that decides whether to process or not the knowledge "delivered" by attention. It determines also the persistence and intensity of such processing.

It is followed by the **intellect** with three instruments at its disposal:

Intelligence, i.e. the "working device" for creation of a response pattern. It is based on full information necessary to develop such pattern and knowledge of all principles of such information processing.

Intuition, which enables guessing the lacking information necessary to start intelligence.

Instinct, both inborn (closed instinct) and acquired (open instinct) that determines the direction of search made by intuition and intelligence.

Then, **prudence** which evaluates the quality of the response pattern produced by intellect. If it is good enough, **decision** gives a signal "Go!" Then **skills** are employed which enable quick and efficient arrangement of a physical response.

The next link is made of **efferent copies**. They enable discerning in the environment the results of one's own actions and phenomena independent of them. Moreover, they make an "archival reference" enabling perfecting a given motor action in the future (if necessary).

Only then does visible **action** come. The general flow of information is shown in a simplified form in Figure 3.

Figure 3 features two loops: the lower one, marked with a continuous line, and the higher one, marked with a dotted line. The former symbolizes the sensory-physiological part of the system, whereas the latter – the intellectually-psychological part. One may compare it to the "two circle" theory by Levan V. Tschaidze, student of Nikolai A. Bernstein [30]. However, Tschaidze's theory constitutes a "structural shadow" with neurophysiological roots, whereas the considerations underlying Figure 3 – a "functional shadow" of motor control of rather psychological nature.

Summing up, directly observable are physical stimuli on the "input side", and visible action (movement) on the "output side". All the processes between them may be analyzed mainly with "free invention" (Einstein) and "careful inference" (Dawkins).

It is worth noticing that even the most advanced contemporary observation devices may detect merely what is going on in neural structures, most interesting of which is no doubt the brain. Nevertheless, even with the most advanced neuroimaging technology, a scientist may only observe which part of the brain is especially active at a given moment, but is not able to state precisely what simply happens in this especially active region; we know merely, for what this or that region is "responsible". Moreover, the brain constitutes – roughly – only the "hardware", whereas the "device" that controls the behavior of living beings, including humans, is the mind. In this field of scientific investigations the best possible research device is the "inference to the best explanation".

While taking the definition of consciousness proposed in this paper, one may trace the roots of it to the A and B levels of the ladder of modalities, but the real "Copernican" revolution in consciousness development happens at the C-level. The remote sense organs enable perceiving one's own body not as a "whole universe", but as a part of a great environment. Only C-level sensory organs – mainly vision – enable detection of movement, and, consequently, time.

Unfortunately, time perception, while connected to direct sensory experiences, makes merely what is termed "timing". Arturo Hotz describes it as follows:

> ***Timing*** *is the temporal punctuality towards a spatial point, and also the functional potential to be at a proper time, with an optimum speed and in a relevant place* [9].

Accordingly, timing may include only a small part of the whole time axis. To grasp it in full, it was necessary to detach reasoning from current environmental stimuli. This became possible when the word had been invented, i.e. an abstract representation of reality immune to time lapse. It is worth mentioning that according to the motor theory of language by Robin Allott, "*the semantic, syntactic and phonetic structures of language developed on the basis of a complex pre-existing system. More specifically, the structures of language were a transfer from or a calque of the structures of the pre-existing motor system"* [10].

Still higher on the scale of abstraction is the E-level symbolic modality, where the abstract representation of reality is detached from real constraints. In short, at the D-level "common reason" representations, the independent values are real spatial-temporal constraints, and the dependent value is an event, which has to be adjusted to them. At the "fantastic" E-level the situation is reverse: The independent value is the event, and the dependent values are the spatial and temporal determinants, deprived of their function of constraints. For example, one may imagine that one crosses the Atlantic Ocean with one step, but it is not possible to perform it in reality. This is why the E-level cannot control any real motor operation.

Conclusion

It seems highly instructive to consider the general idea of Figure 1 from a wider perspective. It means that there is something that may be termed Truth – somewhere and somehow installed in the central body shown in the figure – observable and firmly rooted in reality, and Freedom, elusive and enabling free interpretation of e.g. experimental data and building the reliable mental representation of reality, i.e. theory. It may be compared to Direction, from which the body is being observed; this vividly recalls the allegory of the cave by Plato. Where Truth and Freedom meet one another, Science

is born. However, the way of Truth is firmly connected with reality, whereas the way of Freedom is located in the region of fantasy. Thus, their ways may indeed sometimes confluence, but then they inevitably have to fork. Only such a bifurcation produces a dissonance making the "driving power" for knowledge development, which, while ordered, makes science.

Accordingly, if one comes across such a bifurcation, where the ways of Freedom and Truth move away from each other, it does not mean that "the theory has been refuted". According to Karl R. Popper, the refutability itself makes one of the main attributes of what can be termed "scientific". Thus, theory "lives" in the region of abstraction and gains its validity on the basis of reasoning, and not observation of reality so it cannot be "refuted", since in reality one observes a phenomenon or process which cannot be explained with a given theory. For example, the invention of quantum physics did not invalidate the Newtonian rules, but merely marked limits beyond which classical physics loses its applicability.

However, physics deals mainly with observable objects. Biologist Jack Cohen and mathematician Ian Stewart wrote:

> *Physics takes a pragmatic and severely critical stance. It concentrates on simple, highly controlled systems; in return it expects impeccable agreement between experiment and theory (…). Physics deals with an invented, simplified world. This is how it derives its strength; this is why it works so well. (…) Sciences like biology are less fortunate* [31].

As a result, in sciences such as psychology or motor control it is necessary to employ mainly "non-empirical" methodology of intellectual investigations. Here the methodology termed "inference to the best explanation" by Gilbert H. Harman [29] seems to be promising. This makes the process of science development a "never-ending story". Moreover, in the intellectual penetrations of such issues as consciousness scientists cannot get any significant support from experimental research and mathematics. Perhaps this is what makes consciousness probably the most challenging problem to the whole contemporary science.

What this study adds?

The paper follows the idea expressed by mathematician René Thom that contemporary science needs no more data, but rather new interpretations and methods of ordering of the already existing knowledge. The issue of consciousness is of highly abstract nature, and thus it is hardly subject to neither experimental research, nor mathematical explanation. In this situation, a system-theoretical approach, which, e.g., unveils the multimodal structure of consciousness, seems to be promising.

References

1. Boly M, Seth AK, Wilke M, et al. Consciousness in humans and non-human animals. Frontiers Psychol. 2013; 4: 625.
2. Feynman RP. The character of physical law. Random House Inc., 11994, New York, NY.
3. Schmidt RA. Motor control and learning. A behavioral emphasis. Second edition, Human Kinetics Publishers, 1988, Inc., Champaign, Il.
4. Życiński J. Świat matematyki i jej materialnych cieni (The world of mathematics and its material shadows), Copernicus Center Press, 2013, Kraków (in Polish).
5. Sorman G. Prawdziwi myśliciele naszych czasów (Les vrais penseurs de notre temps), Czytelnik, 1993, Warsaw (in Polish).
6. Darwin C. The formation of vegetable mould, through the action of worms, with observation on their habits, 1881, John Murray, Albermale Street, London.
7. Jennings HS. Behavior of the lower organisms. Columbia University Press, 1906, New York, NY.
8. Kaminski MA. Edward Heron-Allen and his theory of "Purpose and Intelligence" in the Foraminifera. In: Whittaker JE, ed., Edward Heron-Allen FRS: Scientist' Proceedings of the 4th Heron-Allen Symposium, 2004, Opusculum VII, Heron-Allen Society, 2005.
9. Hotz A. Qualitatives Bewegungslernen, Verlag Schweizerischer Verband für Sport in der Schule SVSS, 1997, Bern (in German).
10. Allott R. The motor theory of language. In: von Raffler-Engel W, Wind J, Jonker A, eds., Studies in sanguage origins, vol. 2, John Benjamins Publishing Company, Amsterdam/Philadelphia, 1991: 123-157.
11. James W. Some problems of philosophy: a beginning of an introduction to philosophy. University of Nebraska Press, 1996, Omaha, NE.
12. Bernstein NA. O lovkosti i yeyo razvitii (On dexterity and its development). Fizkultura i Sport, 1991, Moscow (in Russian).
13. Bernstein NA. On dexterity and its development. In: Latash ML, Turvey MT, eds., Dexterity and its development. Lawrence Erlbaum Associates, 1996, Publishers, Mahwah, NJ.

14. Miller GA. The magical number seven, plus or minus two: some limits on our capacity for processing information. J Exp Psychol. 1956, 56: 485-491.
15. Nideffer RM. The inner athlete. Thomas Crowell, New York, 1976, NY.
16. Freud S. A general introduction to psychoanalysis. Horace Liveright, Inc., New York, 1920, NY.
17. Bernstein NA. O postroyenii dvizheniy (On construction of movements), Medgiz, 1947, Moscow (in Russian).
18. Bertalanffy L. von, General system theory. Foundations, Development, Applications, George Braziller, New York, 2001, NY.
19. Petryński W. Współczesne teorie uczenia się ruchów i sterowania nimi (Contemporary theories of learning and controlling movements in humans), Górnośląska Wyższa Szkoła Handlowa, 2008, Katowice (in Polish).
20. Petryński W, Feigenberg JM. Emocionalnyje faktory v upravlenii dvizheniyami cheloveka (Emotional factors in motor control in humans), Teoriya i praktika fizicheskoy kultury, 2011: 3-9 (in Russian).
21. Buytendijk FJJ. Allgemeine Theorie der menschlichen Haltung und Bewegung, Springer Verlag, 1956, Berlin – Göttingen – Heidelberg (in German).
22. Kawato M. From understanding the brain by creating the brain toward manipulative neuroscience. Philos Trans Royal Soc B, Biol Sci. 2008; 363: 2201-2014.
23. Heller M. Filozofia nauki. Wprowadzenie (Philosophy of science. An introduction), Petrus, 2011, Kraków (in Polish).
24. Morawski JM. Myślenie systemowe (Systemic thinking). In: Fidelus K, ed., Z warsztatów badawczych. Materiały VIII Szkoły Biomechaniki, AWF, 1989, Warsaw (in Polish).
25. Rochat P. Five levels of self-awareness as they unfold early in life. Conscious Cogn. 2003; 12: 717-731.
26. Pakosz P. EMG parameters and kinesthetic differentiation during the free-throw of basketball players with various levels of athletic experience. Centr Eur J Sport Sci Med. 2013; 2: 31-38.
27. Einstein A. Ideas and opinions. Modern Library, 1994, New York, NY.
28. Dawkins R. The greatest show in the world. The evidence for evolution, Free Press, Simon & Schuster, 2009, New York, NY.
29. Harman GH. The inference to the best explanation. Philosophical Rev. 1965; 74(1): 88-95.
30. Tschaidze LV. Koordynacja ruchów dowolnych i powstanie nawyków ruchowych człowieka w świetle ogólnych zasad sterowania i układów sterowanych (Coordination of voluntary movements and formation of motor habits in humans in the light of general principles of control and controlled systems), "Wychowanie Fizyczne i Sport", 1962; 2: 155-161, (in Polish).
31. Cohen J, Stewart I. The collapse of chaos. Discovering Simplicity in a Complex World, Penguin Books, 2000, London.