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Gestalt Psychology, Mirror Neurons, and Body-Mind Problem

The body-mind problem is one of the oldest philosophical problems. Aristotle claimed the unity of soul and body: "We should not ask whether the soul and body are one, any more than whether the wax and the impression are one" [Aristotle, De Anima ii, 412b6-7]. Plato held the opposite view. Gestalt psychology from the very beginning was concerned with this problem. One aspect of the body-mind problem was presented by Gestalt theory in the form of isomorphism. Another line of investigation started with Gestalt therapy, which pays a lot of attention to body language, body processes, body awareness, and body memories. Neuropsychology continuously accumulated facts concerning relations between psychological functions and neuronal activity. At last, 20 years ago, the fundamental *mirror neurons* phenomenon was discovered: perception through imitating the movements (gestures) that created the stimulus. This discovery demonstrates that our body is an inseparable part of perception. With that knowledge in mind, this paper analyzes the history of Gestalt psychology, and shows that this idea was born in Gestalt psychology and persisted throughout its 100-year history.

A **mirror neuron** (MN) is a neuron that fires both when an animal or human being acts and when the animal or human being observes the same action performed by another. So, when observing the actions of the other, the observer feels as though he is himself acting. Such neurons have been directly observed in primates, humans, and other species including birds. This discovery initiated a wave of research and discussion in psychology of perception and particularly in Gestalt psychology which is the most general theory of perception. The most popular theme became the perception of emotions (partly because that issue had attracted the attention of philosophers, biologists, and psychologists from antiquity on). Was this an unexpected discovery which meant a kind of revolution in neuropsychology? Or was it a logically legitimate step in the development of a psychology of perception? In this paper I will present arguments which support the latter position; during 100 years Gestalt psychology has proposed and developed the idea that the final and crucial part of perception is imitation of movements that created the stimuli (either dynamic or static).

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In 2007 *Gestalt Theory* published a paper ("Gestalt psychology and mirror neuron discovery", by M. Eagle & V. Wakefield [Eagle 2007]) on the MNs phenomenon and its relationship to Gestalt theory. The main statement of that paper is as follows: Köhler and Koffka, from the 1920s through to the 1940s, anticipated the recent discovery of MNs and the current theory of how one person understands another's mental state. The authors of the paper proposed that "understanding another's mental state is largely attributable to the operation of the general principle of isomorphism". I agree with the general statement that during its 100-year history Gestalt psychology has been constantly sending messages to neuropsychology that perception of visual and audio stimuli contains an inseparable motor component, but I oppose the authors' claim that MNs phenomenon and simulation theory are consequences of the principle of isomorphism. My objections were raised after reading the most complete review of the isomorphism principle by Luchins & Luchins "Isomorphism in Gestalt Theory" [Luchins 1999]. It shows that there is no agreement as yet about what isomorphism is: each author uses his own definition of isomorphism, which is different from all others.

I will analyze theories and experimental results accumulated in the psychology of perception (particularly in Gestalt psychology), neuropsychology and Artificial Intelligence concerning movement perception as an inseparable component of perceiving visual and audio stimuli. I hope to prove that Gestalt psychology has during the last 100 years been constantly sending messages to neurophysiologists, attracting their attention to motor areas in the brain when investigating processes of perception. Appropriate attention to these signals would have brought about the discovery of mirror neurons much earlier.

Data from Psychology

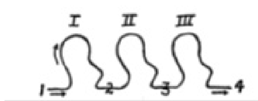
1. Mach and then Ehrenfels analyzed the phenomenon of rhythm. Mach was the first to suggest that in perception of rhythm there are two ingredients: tone-sensation and muscle-sensation. Ehrenfels in 1890 followed him: "Each perceived step from note to note caused in us a characteristic sensation (or feeling) belonging not to the sense of sound but to some other sphere (perhaps involving nervous or muscular sensations)" [Ehrenfels 1890]. I would like to rephrase that utterance to elucidate its meaning: "each note of rhythm caused in us a muscular sensation". In 1905 R. Stetson explained the motor theory of rhythm perception:

> "One has a vivid and satisfactory sense of rhythm when one merely hears (or sees, or feels) the series. Many musicians keep the tact by tapping the foot, and strains of the muscles of the leg often constitute the silent rhythmic response. It is not necessary that joints be involved, but changes in muscular conditions which stand in consciousness as movements are essential to any rhythm, whether 'perceived' or 'produced'" [Stetson 1905].

One can see that the last statement – "movements are essential to any rhythm, whether 'perceived' or 'produced'" – is very close to the idea of mirror neurons. The ability to simulate movements of others is a basic statement of the theory of the functioning of MNs – "simulation theory" – as well.

2. Köhler expressed this idea more explicitly:

> "In the most general case of sensory organization both space and time are involved in the same experience of grouping. A simple example will show what is meant: In a dark room we move a lamp hidden in a box, so that one bright point is the only thing visible on the dark ground. Let us suppose that the point moves in the following form without a change in speed in the form of Fig. 1.



> A naive observer will describe what he has seen as three curious figures or three movements (I, II, III)" [Köhler 1929].

So, Köhler is showing a static curve and without hesitation substitutes the word figures with the word movements.

3. In discussing perception of melody as a phenomenon of the audible domain, Stetson turned his attention to speech perception. He treated it, much like rhythm perception, as a process of imitation movements of the vocal tract that produced the speech: "Speech usually calls up a response in our own vocal organs. When one reads verse silently, the movements are probably movements of incipient articulation in the vocal apparatus." [Stetson 1905]. 50 years later, Liberman proposed the *motor theory of speech perception* based on the same idea [Liberman 1957]. The motor theory of speech perception is the hypothesis that people perceive spoken words by identifying the vocal tract gestures with which they are pronounced rather than by identifying the sound patterns that speech generates. The role of the speech motor system is not only to produce speech articulations but also to detect them. "Infants at four months of age match the sound produced by another with a vocal tract it cannot see, articulators (like the larynx responsible for the matched pitch contours) it cannot feel, and without inordinate numbers of attempts to do so." (Kuhl 1986 (a), 238-240).

4. One of the basic laws of Gestalt perception is the "good continuation" principle. A stimulus in Fig. 2 is perceived as "two crossing lines". What is the meaning of "good continuation"? "Continuation" means a process which develops over time. But the image is final (it does not change over time), so how can we apply a time-dependent process to that unchanging image? In most cases "good continuation" is applied to a line, so, it is a "good continuation of the line". The direct interpretation of the term "continuation" is prolongation of the line, say "ab", beyond the point "b".

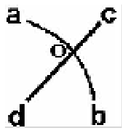


Fig.2

That makes no sense because the drawing is complete, and there is no intention of changing the drawing by elongating this line. The only reasonable interpretation is therefore if "continuation" is applied not to the given image, but to the imaginable process of creating the line. So, in the very beginning of Gestalt theory and in its basic laws was implemented an idea that in our perception we can imitate the movements of another human being, which create the stimulus. The ability to simulate movements of others is also a basic statement of theory of functioning of MNs – "simulation theory".

5. In 1923 Wertheimer wrote: While perceiving drawings "one has a feeling how successive parts should follow one another" during drawing [Wertheimer 1923] (It is worth mentioning that "drawing" means "creating by process of drawing"). It is symptomatic that Wertheimer, such a strong proponent of experimental psychology, allowed himself to use such fuzzy terms as "has a feeling", or "inner coherence", or "good continuation", or "inner necessity". Wertheimer noticed it too and commented: "the reader should find no difficulty in *seeing* what is meant here." He often uses words in quotation marks: "unity", "simple", "complicated". To me it indicates that Wertheimer understood that it is something deeper than the number of laws of grouping, but he couldn't grasp it in precise terms. At the same time in his writings, as well as in the writings of Köhler, Koffka, Metzger and many others gestaltists, we find the idea that perception of movement is an inseparable part of our visual, audio, and tactile perception.

6. Metzger describes in his book [Metzger 1936] a mentally blind man, referring to the famous case of the patient Schn described by Gelb and Goldberg in 1918. He could no longer immediately recognize visual forms. This man was still capable of following visual lines with movements of his head or hand and thereby of recognizing the shape of the lines by the trajectory of these movements. Metzger was the only one in the 100-year history of discussing Schn's case, who brought to the attention of the gestalt community the fact that when Schn followed the trajectory of a written character in the "wrong" direction (in the direction opposite to the movement by which that character is written by the majority of humans) he could not recognize the character. This fact is crucial to the theory of motor perception of linear drawings. As an objection to this theory it could be hypothesized that the movement extracted from the visual domain is not the final product of our perception. It could be assumed that our brain keeps the trace of that movement as a line on the inner virtual "board" and that is where the understanding happens. But that hypothesis contradicts the experimental fact emphasized by Metzger: the pattern on the virtual board will be the same (as well as the final judgment) independently of the direction in which the patient traced the letter, but the patient gave different answers depending on the direction of tracing. This shows that the final decision is made in the motor domain, and the final percept is a gesture.

7. Pinna, while describing perception of different forms, directly describes how the figure was created: "The square is deformed by a scorch", "the glass square is broken in a corner", "a gnawed or nibbled square". "They show the action performed (a *happening*)" that transformed the quadrangle into a given shape. Pinna remarks that "none of these can be fully explained by the forms of grouping and shape." [Pinna 2010]. But both grouping laws and happenings could be explained by a single principle – our perception of linear drawings describes how the stimulus was created (the imitation principle).

8. It is worth mentioning that in the XX century professional musicians, artists, and poets were confident that while perceiving speech, music, and drawings we imitate the movements that produce these stimuli. At the end of the XIX century art critic P. Hamerton says: "Drawing is a motion which leaves significant marks" [W. Walker, Handbook of drawing, Charles Scribner's Sons, 1880]. Here is what professional musicians wrote in a very popular textbook *Elementary Theory of Music*: "a characteristic feature of our perception of a tune is that, while listening to a tune, we consider how we would sing through it, and, regardless of our will, our mind's singing matches the tensing or quieting of the vocal cords". [Alexeev 1986]. It means that we perceive a tune by imitating the way the tune could be reproduced, and the only instrument a human has for that is his vocal cord. It is appropriate to mention that melody comes from the Greek word μελῳδία (*singing).* The Koday, Suzuki, and Orff methods of musical education are based on the premise that children learn to play instruments through listening and imitation.

9. A similar point of view was expressed by the famous musical educator Edwin Gordon: "Through the process of audiation (i.e. inner musical hearing), we sing and move in our minds, without ever having to sing and move physically" [Gordon 1997]. "Qualified musicians must be able to do the following: sing what they have played; play a variation of the original melody; play the melody in a different key and tonality [Gordon 2001] – all of which means that what we really get, when listening to a melody, is not a sequence of pitches but an abstraction, a generalization, a Gestalt. There are neurophysiological evidences that we perceive melody in terms of its production. Brodsky et al. (2008) found a subtle activation of the vocal cords during audiation (audiation is the ability to internally "hear" the music one is reading before physically hearing it performed on an instrument. The researchers inferred that this process serves as an efficient way of reading music).

10. It is remarkable how the relationship between music and poetry was described – not as a connection between the music and the speech but as a relationship between rhythmic movements of legs and movements of lips:

> "In the beginning, out of the mists of Time, hand in hand, came those twin sisters of Art, Music and Verse. Man, in the exuberant infancy of the race, instinctively danced, and as he danced he sang. The rhythm of his lips gave the rhythm to his foot, and the rhythm of his foot gave the rhythm to his lips; the two interchangeably linked. Thus was the birth of literature in music" [Dabney 1902].

11. Sevastianov wrote an essay under the title "Drawing as a movement", declaring that "communication between people is enclosed by means of drawing: all drawings are traces of movements left on the surface. A drawing, as any other piece of art, carries emotions from artist to spectators." [Sevastianov 2012]. Art teacher Konotopov stated that "by learning to draw, a child acquires the ability to see the consequences of his actions, to look at himself from outside. This happens because a child's doodle is a motor Gestalt and visual Gestalt at once." [Konotopov]

Over the past 100 years, Gestalt psychologists have developed and promoted the idea that movements are an important part of perception and understanding in the visual as well as the audio domain. Concerning audio dynamic stimuli (like rhythm), it was overtly claimed that movements are essential to the perception of rhythm, whether perceived or produced. Perception of movements producing rhythm includes simulation of these movements by the listener (sometimes explicitly and sometimes implicitly) – a precise description of mirror neuron functioning. Wertheimer then Metzger were describing an even more revolutionary idea: our nervous system is able, by looking at a stable linear drawing, to restore the movement that a long time ago created that drawing. Then Pinna showed that our brain is able to separate lines in the drawing which were created by a pen, and lines which were created by physical force ("broken"), or heat [Pinna 2010]. The questions this raised for neurophysiology will be discussed later.

Data from Neuropsychology

In 1918 Goldstein & Gelb published a paper that had a lasting impact on the development of neuropsychological knowledge on perception [Goldstein 1918]. They presented a case describing a mentally blind man 24 years of age (Schn).

> "He was wounded in June 1915: two wounds at the back of the head, one clearly penetrating into the brain, the other (just above the left ear) possibly less deep. In February 1916, when he was transferred to the Hospital for Brain Injury, Frankfurt am Main, his ability to speak was not disturbed; he was also able to read. The patient was orderly and quiet; his attention seemed rental and he followed with interest the experiments we conducted. His visual perception was not normal and was classified as psychical blindness. Line drawings were unrecognizable and it was

> found that in reading he had to trace each letter of every word with his finger. In general we found no reduction of Intelligence in this patient.
>
> When words were presented tachistoscopically, however, the patient failed completely (even when the exposer was increased to 1 – 2 sec). That was the more puzzling because the patient could read and draw (unusually well) and was also able to recognize and describe objects in his ordinary environment.
>
> We began our study, therefore, by investigating the patient's ability to read. The patient was able to read almost any text given him. Careful observation eventually enclosed that his 'reading' was accomplished by a series of minute head- and hand-movements—he 'wrote' with his hand what his eyes saw. He did not move the entire hand as if across a page, but 'wrote' the letters one over the other, meanwhile 'tracing' them by head-movements. An especially interesting aspect of the case was the patient's own ignorance of using this method. Even after our discovery we found it difficult to persuade him that his procedure was not the customary one. He showed very clearly that he considered it inevitable for people to 'read' in this way.
>
> Our further findings were:
> If prevented from moving his head or body, the patient could read nothing whatever. His movements led to reading only If they corresponded to normal writing movements. If required to trace a letter the 'wrong' way, he was quite at a loss to say what letter it was.
>
> If a few crosshatching marks were drawn across the word, he followed them when he reached them and consequently lost all sense of what the word was. It shows that while tracing the line the word as a whole was not present in patient perception".

This became one of the classic cases in neuropsychology. This case has contributed to the refinement of the Gestalt psychological theory of visual perception, and was referred to by Köhler and Metzger to support their point of view. Goldstein and Gelb presented this case to support the idea of Gestalt. They claimed that the patient was unable to organize local feature elements into a larger, more coherent "whole" – a Gestalt. Köhler in 1929 used the case to argue for an explanation of Gestalt perception in the visual field in terms of our sensations of eye-movements. The case shows

> "how much motor function, accompanying vision, depends itself upon normal visual organization. Organization being a matter of extended regions of the field, wherever only local fractions may become organized to some degree, the control which organization in a large area normally exerts upon the motor function, is made impossible, and results like those I have just mentioned become inevitable." [Köhler 1929]

Metzger in 1936 continued this argument against making eye-movements responsible for compensation referring to the same case but in more detail.

> "There is hardly any prominent property of shape perception and perceptual segmentation that someone has not yet tried to attribute to eye motions; this was proposed most recently, for instance, for the law of good continuation. For some time it was even believed that we really do not see the basic shapes of things at all, but become aware of them only by eye movements made while exploring those shapes visually" [Metzger 1936].

Metzger presented experiments which show that eye movements could not adequately trace simple isolated forms (circle, triangle, and quadrangle). He also refers to Schn's case: when his head was fixed he recognized nothing. This led to the Gestalt-like theories: 1) agnosic patients are able to recognize individual features, but cannot synthesize a whole concept from the parts, and 2) the ability to recognize shapes through body movements is a compensatory mechanism, which is mobilized only in pathological situations.

> "This theory was popular because it had several strong supporting points: one is the frequency with which it explains otherwise puzzling clinical findings and the second concerns the utilization of nonfocal, but wide-spread cerebral abnormality. Interestingly, this explanation of visual agnosia has enjoyed somewhat of a renaissance recently under the label integrative agnosia" [Marotta 2004].

Schn's case was used by Merleau-Ponty to claim that there are two distinct ways in which we can understand the place of an object when we are visually apprehending it [Merleau-Ponty, 1962]. The first is essentially cognitive or can serve as the input to cognitive processes; the second irreducibly involves a bodily set or preparation to deal with the object. Because of its essential bodily component, Merleau-Ponty calls this second kind of understanding motor intentional: "There is an independent stream of visual information that is directly tied to action.

The existence of an individual who showed a breakdown in Gestalt processing after brain damage, served to reinforce that era's ideas about visual perceptual organization" [Merleau-Ponty, 1962].

Data from AI

My personal road to Gestalt psychology and through Gestalt psychology was always navigated by my work on computer programs that simulate human abilities to recognize and understand (Artificial Intelligence). In psychology there have always existed different schools with different theories of many psychological phenomena. While searching for truth and discussing the problem, every party has scientific status and appropriate funding. The situation in Artificial Intelligence is quite different. Nobody can convince the computer that a particular theory is good even if the author is professor of computer science at MIT or Nobel prize-winner in economics. If computer programs are based on wrong principles they will not solve problems. I started in the 1960s at the Institute of Applied

Mathematics in Moscow. I had tight scientific and personal connections with an informal association of outstanding scientists representing a group of sciences vitally important to Artificial Intelligence (AI): mathematics, computer science, psychology, and neurophysiology. They were Bernstein, Luria, Gelfand, Tsetlin, Gurfinkel, and Bongard. They founded the informal Moscow School of Artificial Intelligence.

Handwriting recognition

My first problem in AI was computer handwriting recognition. At that time there were a number of publications on this issue. There had been some achievements in recognition of separate characters but very little progress in recognition of cursive scripts (connected characters). All authors treated handwritten characters as geometrical objects and described them either as a set of black dots on the raster, or as a set of circles, loops, arcs, strokes, tips and so on. When I started that project, I didn't have the equipment to load the scripts onto the computer. So, I decided to present the writing as a sequence of numbers – points (x, y) along the trajectory of writing. Working with the trajectory, I very soon recognized that the script is a combination of a small number of basic elements of trajectory – seven in total. It happens that at the same time I attended Luria's seminar on neuropsychology in the Moscow hospital of brain surgery. At one seminar the case was demonstrated of an engineer who had lost the ability to read handwriting. During rehabilitation he was learning to recognize handwritten characters by following the trajectory with his finger. Six months later he was able to read handwriting keeping the right hand deep in his pocket but still following the trajectory of the character with the tip of his finger. The case induced an idea that the trajectory is an essence of human perception of scripts. This idea got immediate support from common experience. When I deal with illegible writing I try to make it out by tracing the path of the pen. When my children started to learn the alphabet I played with them by writing characters with my finger on their backs which they succeeded in recognizing. Children start to read cursive scripts only after they learn to write cursive.

Such understanding of the handwriting recognition problem allowed me to concretize some general ideas in pattern recognition. At that time Gelfand and his co-workers published a paper which stated that for the purpose of recognition the key issue is an *adequate language* of the object's description, and that that choice is more important than particular recognition algorithms [Vasiliev 1969]. Because in my approach to handwriting recognition I changed the language of description it raised a question – is it an adequate language?

An idea for how to build an adequate language came from Michael Bongard's book "Pattern recognition" [Bongard 1970] – it was the *imitation principle*. The common concept of pattern recognition contained three ingredients: the objects to be recognized, the recognizer (computer program), and the investigator, who defines the problem, defines the presentation of the objects (description), and chooses the recognition program. Bongard added a fourth ingredient – the device, which creates the objects of recognition. He insisted that the creative device and recognition device have to be of the same level of complexity. More precisely, both must have the same set of inner states. The goal of developing a good recognizer can then be achieved by putting the recognizer in a state equal to that in which the creator device generated the objects to be recognized. In other words, the recognizer has to *imitate the creator*. From this follows that an adequate description of the objects presented to the recognizer is a description of *how the object was created.* Because a script was created by the movement of the pen, the description of the trajectory of the pen *is an adequate language* for the problem of handwriting recognition. So, we found an answer to our question – we choose an adequate language for recognizing handwriting.

In other words, we perceive the written characters not as geometrical objects but as a movement complex, as a dynamic stereotype, or, in modern terminology, as a "writing gesture". 30 years later, on the wave of simulation theory, D'Ausilio et al. proposed "a modified *motor theory of speech perception* according to which speech comprehension is grounded in motor circuits..." [D'Ausilio 2009], and Liberman & Mattingly stated that "the objects of speech perception are the intended phonetic gestures of the speaker, represented in the brain as invariant motor commands" [Liberman 1985].

Now the model of handwriting perception looks as follows. We perceive the static stimulus, the script, and at the higher level of visual tract we restore the trajectory – the movement of the pen in the process of writing the given script. That is the percept that gives us the ability to understand the text. As the case presented by Luria (see above) shows, the patient perceived all geometrical characteristics of the stimuli, and even saw the trajectory, but when he could no longer reconstruct the movement of the pen, he could no longer understand the message. Based on that model I developed a program for handwriting recognition [Guberman 1976]. But it was to take 15 more years before a small Russian-American company "Paragraph" started to develop a computer application for handwriting recognition based on these ideas. Until that moment dozens of algorithms were proposed and tested, and hundreds of millions of dollars were spent worldwide by small and big companies with no success. All of these algorithms were based on mathematical and engineering approaches. In 1991 "Apple Computers" licensed from "Paragraph" the recognizer. Then the technology was licensed in the USA (by Boeing) and Germany (by Siemens) for automatic mail sorting. Meanwhile another giant - Microsoft - continued attempts to create original software, spent another 100 million dollars and 10 years later licensed the technology from "Paragraph". That is the price they have to pay for neglecting psychological knowledge when trying to create computer programs that imitate human intelligence.

Speech recognition

During all the years of developing handwriting recognition, works on speech recognition were continuing in parallel. The direction of development was similar to that in handwriting, with most work being done in mathematics and engineering. The basis of speech recognition was much more solid than the basis for handwriting – 50 years of successful development of music and speech recording, transferring, transforming, and compressing. The main tool for all this was spectral analysis. Accordingly, in speech recognition everyone used spectral description of sounds. The results were similar to handwriting: that is, very limited. At that time (in the 1970s), after I published the paper on handwriting, I strongly believed the imitation principle to be a good psychological tool for communication problems. So, I decided to apply that principle to speech recognition.

The crucial point of any recognition problem is the language for describing the objects. According to the imitation principle, for communication problems the adequate language is the language which describes the process of creating the objects of recognition. Sounds of speech are produced by the articulation tract, so they have to be described by their articulation – *articulation gestures* – and that is how we percept speech. There are some disconnected facts of speech perception which support this view. There are people who can imitate other people's speech very well. To me it means that people understand the movements of the articulatory tract of a speaker and therefore can imitate it. I learned also that students that squeeze a pencil between their teeth make more mistakes in spelling, because some articulatory muscles are busy with another job: the perception of the phoneme as articulation gestures leveled the differences between phonemes. Some ideas can be found from psychological experiments, and once more I referred to Luria's description of brain damage resulting from head traumas acquired during World War II [Luria, 1970]. Many cases report misinterpretation of some consonants or group of consonants, but no case describes difficulties in recognizing vowels. This brought me to the understanding that terms of description are different for vowel and consonant articulations. It is generally accepted that each vowel is mainly determined by the relationship between the volume sizes of the front and the back of the articulatory apparatus. It is defined by horizontal position of tongue (back-forth). Most consonants can be described with 3 parameters: 1) place of articulation (lips, teeth and so on), 2) time pattern of interaction with the articulatory apparatus (explosive or not), and 3) voiced or not voiced sound.

By the way, in analyzing post-traumatic aphasias Luria found that there is a module in the brain that deals with "homorganic sounds", i.e. place of articulation. Each sound of speech has a unique combination of articulator parameters, a unique dynamic of articulatory tract, a unique articulation gesture. Each such gesture corresponds to some phoneme. A phoneme has been defined in linguistics as an abstract minimal distinctive part of speech. It doesn't have a physiological or physical embodiment. In my opinion there were no objections to the claim that articulation gestures function as phonemes. As phonemes do, they appear in spoken speech in different physical embodiments depending on the size of the body, gender, age, and medical conditions – they are real invariants of the speech.

One of the fundamental features of a phoneme is that it is "abstract". This emphasizes the fact that it has no representatives in the audio domain. The proposition that articulation gestures are phonemes perfectly meets this characteristic: they do not belong to the audio domain and therefore cannot be concretized, i.e. described as a sound.

Let us remember that Ehrenfels introduced the notion of Gestalt to exhibit what is common in physically different sequences of tones which we perceive as the same melody. Articulation gestures present all possible variations of a phoneme in speech; they are a generalization of all of them. Taking all of this into consideration, we have to claim that the articulation gesture is the Gestalt of a sound of speech, and the description of that Gestalt has to be done in articulation terms, for example, the Gestalt of "p" is "labial, explosive, not voiced" (similarly the Gestalt of melody, which is expressed in a musical language and notation system) [Andreevsky & Guberman 1996].

At that point in my work I recognized that a similar approach to speech recognition had been proposed 10 years earlier by Liberman [Liberman 1957]: it was the *motor theory* of speech perception. The motor theory of speech perception claims that people perceive spoken words by identifying the vocal tract gestures with which they are pronounced rather than by identifying the sound patterns that speech generates. As everybody can see, my model of speech perception repeats the motor theory of speech, but for me that is not the point. For me the point is that I didn't develop the theory by analyzing experimental data – I derived the theory from a theoretical principle of imitation. That gave me a big push forward to elaborate different consequences of the imitation principle. The principle was fruitfully applied to recognition of 3-D bodies, to face expression recognition, to analysis of articulatory rhythm in poetry [Guberman 1980, 1985].

All the time I was working on handwriting and speech recognition I was studying classics of Gestalt psychology. I was looking for prompts and support for the main idea of the imitating principle: we perceive line drawings as tracks of movement. I addressed these issues in detail in part I and part II of this paper. Here is the list of these clues in short.

> "Each perceived step from note to note caused in us a characteristic sensation (or feeling) belonging not to the sense of sound but to some other sphere (perhaps involving nervous or **muscular** sensations)" [Ehrenfels 1890].

The only reasonable interpretation of "good continuation" is that it is applicable not to the given image, but to the imaginable process of creating the line. At the very beginning of Gestalt theory and in its basic law was implemented an idea that in our perception we imitate the movements of another human being. While perceiving drawings "one has a feeling how successive parts should follow one another" during drawing [Wertheimer 1923]. It is worth mentioning that "drawing" means "created by drawing".

"A naive observer will describe what he has seen (it is a three waves curve – S.G) as three curious figures or three movements" [Köhler 1929]. It is remarkable that Köhler without hesitation substituted the word *figures* with the word *movements.*

Metzger describes a mentally blind man. He could no longer immediately recognize visual forms. This man was still capable of following visual lines with movements of his head and thereby of recognizing the shape of the lines by the shape of these movements.

Pinna, while describing perception of different forms, directly describes how the figure was created: "The square is deformed by a scorch" [Pinna 2010].

All this shows that Gestalt psychology was permanently sending a message that movements ("motorium", to use Koffka's term) are deeply involved in perception. The data presented above allow us to express this idea in three particular statements about the perception of communication messages, which establishes the connection between Gestalt psychology and neural neurons phenomena.

1. To extract the meaning of communication messages (speech, writings, drawings, music, gestures, dancing), we percept the movements that create the message: for handwriting and linear drawings, movement of the pen; for speech, movement of the articulator tract (tongue, lips, chin, glottis); for emotions, movements of eyes, cheeks, lips, eyebrows. This echoes simulation theory, which explains the functioning of mirror neurons: humans make sense of the behaviour of others by activating mental processes that, if carried into action, would produce similar behavior.

2. Gestalt is a generalization. The same was found while investigating mirror neurons: "Further research has found that different mirror neurons respond to observation and action stimuli at varying degrees, and show generalization abilities across tasks". (Tutorial in Neurophysiology, Gordon College, MA, USA). "Mirror neurons have the property to generalize the meaning of the observed action independently of its specific features" [Ferrary 2005].

3. Gestalt perception gives us not only the ability to adequately perceive, recognize, and generalize objects, but also the ability to understand the intention of the respondent. The same claim exists in the description of the mirror neurons system: “Premotor mirror neuron areas—areas active during the execution and the observation of an action—previously thought to be involved only in action recognition are actually also involved in understanding the intentions of others” [Iacoboni M. 2005].

Reopening Schn’s case

The case presented by Goldstein & Gelb in 1918 was partly discussed above. The contemporary evaluation of the case is as follows:

> “According to Goldstein and Gelb, Schn’s perceptual problems reflect impairment in integrating local form elements into more holistic shapes and his “piecemeal” approach to object identification appears to reflect a problem in grouping local form information. It showed a breakdown in Gestalt processing after brain damage, served to reinforce that era’s ideas about visual perceptual organization” [Marotta 2004].

But, as a matter of fact, it seems that by following the line of argumentation presented above the case contains more important facts and ideas. Here are some facts from the case and their analysis.

1. Quotation: *“His ‘reading’ was accomplished by a series of minute head- and hand-movements—he ‘wrote’ with his hand what his eyes saw.“*

To my understanding it means: the patient sees the trajectory. The patient can trace the trajectory with his eyes without touching it (in contrast to the other case, in which the patient had to touch the trajectory with his finger). His “tracing” did not follow every line but consisted of marks sometimes differing from the presented letter. These marks constituted for him, however, a motor “alphabet” by means of which he was able to read. 70 years later, when a computer program which imitated humans’ ability to read scripts was developed, a set of basic movements of cursive writing was defined consisting of 8 elements [Guberman 1976]. Here are the elements: .(the first and last are the same). It is not a surprise that the elements from which Schn constructed letters for his “motor” alphabet (which were explicitly mentioned in his file) coincide with some of these 8 elements: arc, loop, circle, straight line. We can also observe more similarity between Schn’s movement elements and the mentioned 8 elements. These 8 elements are connected through some formal relations: 1) they constitute an ordered sequence, and 2) in fast cursive writing each element can be transformed into another one, but only if it is his neighbor in that ordered sequence. For instance, element  can be transformed into  , element

O into λ. It is remarkable that Schn intuitively understands and uses these relations in reading. For instance, Schn copies little cursive 𝓁 as ł. It means that he understood that ∧ - element can substitute λ- element. In another case he traces 𝔐 as 𝓂, in which he substitutes the first two vertical strokes with two λ- elements. Even the letter 𝓈 as copy of 𝔖, which authors qualified as almost unrecognizable, has a reason: the last stroke, which appeared after canonic 𝔖, is, as a matter of fact, a natural connection with the following letter. The tendency to add to the end of the canonical letter a connector is typical in cursive: a, d, u etc. Schn sometimes adds that appendix and sometimes omits it: 𝓊 and 𝒰, when he traces 𝔘 and 𝔄 .

2. Despite his lack of memory images, he could nevertheless draw pictures very well, but he could not, however, copy them: when specifically instructed to do so, he was incapable of drawing a single line. His procedure was of a very different order: having "traced" the presented object in his accustomed way (head-movements) he would then draw a picture of his own of that type of object. He did not reproduce the particular object shown him, but rather its class or type. He drew a boot, not the boot that had been presented. So, in looking at the picture of a boot Schn perceived the generalization of the stimulus – the Gestalt.

By moving his finger along the trajectory, the patient repeats the movement of the writer's pen. According to the definition in the Merriam-Webster dictionary, "to do the same thing as someone" is imitation. As soon as the word imitation (and synonyms like simulation, echoing, mirroring etc.) is pronounced it opens a completely new set of ideas. It opens a new channel of communication with a characteristic language of description – the language of movements. We can perceive movements directly through tactile sense but it demands physical contact that limits both the amount of information we can get and its value for survival. But the patient Schn demonstrated the ability to receive information about somebody's movements encoded in visual stimuli. At the time when Schn's case was published (1918), the motor theory of music perception already existed. This theory claims that movements producing music are encoded in the sounds of music and can be perceived and repeated by humans. In 1957 the motor theory of speech perception was presented [Liberman 1957]. It was also shown that during speech perception articulatory muscles are innervated. In 1967 was published the imitation principle of communication between autonomous systems: to understand perceived messages one has to interpret them in the same terms as they were produced by the sender [Bongard 1970]. In 1975 was published a solution of the computer handwriting recognition problem based on the motor theory of handwriting perception [Guberman 1975]. This had a commercial success and was licensed by both software giants - Apple Computers and Microsoft.

3. Schneider et al. described a patient NN

> "who was only able to recognize single letters or numbers. She could read whole words and 3-digit numbers if she was allowed to observe the examiner writing. If she briefly interrupted the writing she could not find the end of what she had written previously. She was totally incapable of identifying any form or of following it with a pencil. She recognized drawings of single thin straight lines or a circle" [Schneider 1991].

Both patients (Schn and NN) lost the ability to read handwriting and linear drawings. But Schn was able to trace the trajectory of writing, i.e. restore the movement of the pen which created that writing, transform the tracing by vision into kinesthetic signals (the real movement of hand or head), and therefore recognize the letters. NN lost the ability to follow the trajectory, and therefore couldn't restore the movement of the pen, i.e. didn't perceive the letters in terms of their inner kinesthetic code – that is, the gesture description. But when she got the movement of the pen along the trajectory directly from observing the examiner's movements, she transformed that dynamic visual percept into a motor percept, and understood the writing. But that is exactly the description of mirror neurons system functionality: to transfer observed movement – an event in the visual domain – into the motor domain as a copy of somebody's neuron activity which created that movement.

There is one more detail that has to be mentioned: NN recognized only **thin** straight lines or circles. It indicates an additional problem compared to Schn – she can't transform the real line (which always has some width) into the one-dimensional trajectory of the pen. That problem is well known in computer image processing: transforming a real line to one pixel line is not a trivial problem, and it still has no complete solution.

So, there are four paths of reading handwriting: 1) extracting the trajectory from a visual stimulus and then transferring it into kinesthetic code, 2) tracing by inner vision the trajectory, transforming it into physical movements of head or hand, and using the obtained kinesthetic code for recognition, 3) observing the process of writing, and 4) when letters are written on the hand (or back), transferring the tactile dynamic stimulus to the motor domain (see part II of Goldstein & Gelb's paper [Goldstein 1920]).

4. Quotation: *"He did not move the entire hand as if across a page, but 'wrote' the letters one over the other, meanwhile 'tracing' them by head-movements."*

This means that Schn didn't grasp the "whole" (the word) – he read it letter-by-letter, dividing up the word. The idea that first we grasp a word as a "whole" and then recognize the characters appeared on the assumption that the percept from which we extract meaning appears as a whole word. But if we accept the model that before finding the meaning of the stimulus it has to be presented as a trajectory, as a function of time tracing the trajectory takes time. While moving along the trajectory we are reading letter-by-letter, and using additional information (like length of the word from visual channel, inner vocabulary, context, etc.) to expedite the reading. From that point of view the patient Schn suffered not from an inability to integrate local features into the "whole" (integrative visual agnosia), but from an inability to transform the percept from 2-D geometrical space into the space of movements.

Conclusion

Now we can try to answer the question which was raised at the beginning of this paper: what is the relationship between Gestalt Psychology and the mirror neuron phenomenon? Was the latter an unexpected revolutionary event, or was Gestalt psychology pregnant with the idea of communication through imitation of a correspondent's movements? Having looked at the history of Gestalt psychology and adjoining domains (neurology, neuropsychology, Artificial Intelligence, and theory of art) over more than a century, we see that theories (as well as clinical and experimental data) have claimed that a substantial part of perception is the perception of movement encoded in visual and audio stimuli. This line of reasoning started with Mach's "muscle sensation" and was continued by Münsterberg, Wertheimer, Gelb & Goldberg, Köhler, Metzger, Merleau-Ponty, and Pinna. The essence of perception of a wide class of visual (linear drawings and scripts) and audio (speech and music) stimuli is imitation (or simulation, echoing, mirroring etc.) of a correspondent's movements. It concerns not only perception of real-time movements but also perception of static stimuli, which are perceived as movements that created them in the past. But all facts supporting this idea were always treated as artifacts, as compensating mechanisms, which don't work in the intact brain. Even Gelb & Goldberg when describing the phenomenon "reading through tracing" by patient Schn always keep the word "reading" in quotation marks, indicating that it is unnatural reading and has nothing to do with the real mechanism of reading.

The idea of "reading through tracing" was found so unacceptable by the community that a number of papers appeared declaring that this phenomenon is a fake. One of the statements was that Schn was able to write or draw simple forms and seemed to switch into his tracing routine only when performing tests for psychologists. Jung wrote that the 5–10 seconds needed for recognizing a word "were filled by conspicuous movements of either the head or the hand" [Jung 1949]. Today there is no doubt that the "reading through tracing" phenomenon really exists because many patients spontaneously use quite laborious and time-consuming tracing strategies of the hand or head to aid in the recognition of visual objects (Benson & Greenberg, 1969; Campion, 1987; Landis et al., 1982).

Here is one more example of neglecting the phenomenon of "reading through tracing". As was mentioned above, Schneider et al. reported about a woman "who was only able to recognize single letters or numbers. She could read whole words and 3-digit numbers if she was allowed to observe the examiner writing". Then follows a strange explanation with no proof: "In our patient the observation of the examiner writing may have attracted our patient's visual attention" [Schneider 1991].

How did it happen that so many clinical and experimental facts as well as productive hypotheses were ignored? One of the reasons is the fact that the process of transforming visual or audio signals into movement is completely unconscious. Goldstein & Gelb found this from the very beginning:

> "An especially interesting aspect of the case was the patient's own ignorance of using this method. Even after our discovery we found it difficult to persuade him that his procedure was not the customary one. He showed very clearly that he considered it inevitable for people to 'read' in this way" [Goldstein 1918].

Why does it happen? I can't answer this question, but in the history of science it happens again and again. Ironically Metzger met same problem: "Knowledge of physiology has again and again obstructed and diverted the discovery and recognition of the actual laws of seeing" [Metzger 2006].

The same theme appears in the writings of N. Bernstein – an outstanding Russian neuropsychologist of the 1950s and 1960s:

> "Men born blind develop inside an afferent field so similar to the spatial field of sighted persons that they don't fall into contradictions with sighted persons on either geometrical presentation or spatial *motorium*. After the afferent field is finally developed, it puts aside sensations (tactile, vestibular, proprioception, locomotion etc.), which initially helped to build that field, to such a degree that following their tracks in the created afferent field by means of introspection **becomes impossible**."

Really, in psychology many ideas and hypotheses were initiated by introspection. But the idea that when we are looking at a page with writing we percept the movement of the pen that happened 100 years ago, or when we are listening to somebody's voice we percept movements of his tongue, lips and chin – this has no chance to appear from introspection. In 1947 Köhler wrote in his book a chapter "Criticism of introspection" [Köhler]. Many adepts of the motor theory of perception explain why many psychologists ignore the motor perception by the fact that "reading by tracing" is completely unconscious. Merleau-Ponty claimed: "If there is an independent stream of visual information that is directly tied to action, then perhaps this kind of motor intentional understanding even for normal subjects is a kind that we can't reflectively access as such" [Merleau-Ponty, 1962].

History knows of much more prominent cases in which facts have been ignored by scientific communities. In XIX century doctor Ignác Semmelweis at Vienna General Hospital´s First Obstetric Clinic discovered that the incidence of puerperal fever could be drastically cut by the use of hand disinfection. Hand-washing reduced mortality from ~ 20% to below 1%. Despite various publications of results, Semmelweis's observations conflicted with the established scientific and medical opinions of the time and his ideas were rejected by the medical community. He was dismissed from the hospital and harassed by the medical community. He died in an asylum at age 47. In that case we know at least some reasons for such behavior: some doctors were offended at the suggestion that they should wash their hands, feeling that their social status as gentlemen was inconsistent with the idea that their hands could be unclean.

Looking back we see that the idea of perception through imitation of the movements (gestures) that created the stimulus was born and persisted during the 100-year history of Gestalt psychology. This line of development was successfully concluded by the discovery of mirror neurons. That approach to the body-mind problem reflects the philosophical basis of Gestalt psychology – dominance of whole over its parts: the body and the mind could be understood only as interconnected parts of the phenomenon of the man. Before we thought that perception starts with sensations and finishes with Gestalt – the pure product of mind. Now we see that (at least in communication tasks) the percept is embodied in our physical body. The perception will change dramatically if our body changes. Is it not a solid argument in support of Aristotle's idea about the unity of body and mind?

The imitation concept developed in Gestalt psychology is broader than the simulation theory, which describes the functioning of mirror neurons. A special kind of space form – linear drawings – has always been in the focus of Gestalt psychology. Perception of linear drawings is executed through imitation of movement of the stylus. So, the perception of a completely static stimulus (drawing or script) is transformed into a dynamic process – a process which develops over time. This is a good reason for neuropsychology to investigate the neuron mechanisms underlying this phenomenon.

Summary

Thirty years ago a fundamental *mirror neurons* phenomenon was discovered – perception through imitating the movements (gestures) that created the stimulus. This discovery demonstrates that our body is an inseparable part of perception. If now, with that knowledge in mind, one analyzes the history of Gestalt psychology, one will find that this idea was born in Gestalt psychology and persisted throughout its 100-year history.

It is a line of reasoning that started with Mach's "muscle sensation" and was continued by Münsterberg (motor theory of speech perception), Wertheimer ("good continuation"), Gelb & Goldberg ("reading through writing"), Köhler (describing "figures as movements"), Metzger (emphasizing the crucial importance for perception of handwriting of the *direction* of movements), Merleau-Ponty (introducing "*motor intentional* understanding"), and Pinna (extending the concept of perceiving linear drawings as a movement to perceiving them as products of a variety of other physical actions: "fritted" or "broken" or "nibbled" squares).

In parallel, when computers began to play a role in research, similar ideas appeared in the field of Artificial Intelligence (AI). Lieberman proposed the motor theory of speech perception, and Guberman the motor theory of handwriting perception. Bongard published his imitation principle of communication between systems: in order for received messages to be understood they have to be described in language which describes how they were made.

The Gestalt theory proved that the perception of a completely static stimulus (drawing or script) is transformed into a dynamic process – a process which develops over time. It is a good reason for neuropsychology to investigate the neuron mechanisms underlying this phenomenon.

Keywords: Gestalt psychology, Artificial Intelligence, mirror neurons, imitation principle.

Zusammenfassung

Vor 30 Jahren wurde ein grundlegendes Phänomen, nämlich das der *Spiegelneuronen* – Wahrnehmung durch Nachahmung derjenigen Bewegungen, die den Stimulus erzeugten - entdeckt. Diese Entdeckung beweist, dass unser Körper ein untrennbarer Teil der Wahrnehmung ist. Wenn man nun mit diesem Wissen die Geschichte der Gestaltpsychologie analysiert entdeckt man, dass dieses Konzept aus der Gestaltpsychologie stammt und durch deren 100jährige Entwicklung Bestand behalten hat.

Die Argumentationslinie begann mit Mach´s „Muskelempfindungen" und wurde weitergeführt von Münsterberg (Motor-Theorie der Sprachwahrnehmung), Wertheimer („Gesetz der guten Fortsetzung"), Gelb & Goldstein („Lesen durch Schreiben"), Köhler (der „Figuren als Bewegungen" beschrieb), Metzger (der die entscheidende Bedeutung in der *Richtung* der Bewegungen bei der Handschriftenwahrnehmung hervorhob), Merleau-Ponty (der das „Verständnis der *Bewegungsbewußtheit*" einführte), bis zu Pinna (der das Konzept zur Wahrnehmung linearer Zeichnungen dahingehend erweiterte, diese als eine Bewegung infolge einer Vielfalt anderer physischer Handlungen wahrzunehmen: „auslaufende" oder „gebrochene" oder „angeknabberte" Vierecke).

Parallel dazu tauchten, als Computer in der Forschung Bedeutung erlangten, ähnliche Vorstellungen im Forschungsfeld der künstlichen Intelligenz (AI –Artificial Intelligence) auf. Liberman stellte die Motor-Theorie der Geschwindigkeitswahrnehmung auf, und Guberman die Motor-Theorie der Handschriftenwahrnehmung. Bongard veröffentlichte sein Nachahmungsprinzip der Kommunikation zwischen Systemen: um empfangene Nachrichten zu verstehen müssen diese in der Sprache wiedergegeben werden, die auch beschreibt, wie sie verfasst wurden.

Die Gestalttheorie belegt, das die Wahrnehmung eines vollkommen statischen Stimulus (Zeichnung oder Schrift) in einen dynamischen Prozess umgewandelt wird – ein Prozess, der sich innerhalb einer Zeitspanne entwickelt. Für die Neuropsychologie ist dies ein guter Grund, die neuronalen Mechanismen zu erforschen, die diesem Phänomen zugrunde liegen.

Schlüsselwörter: Gestaltpsychologie, künstliche Intelligenz, Spiegelneuronen, Nachahmungsprinzip.

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