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Towards Better Understanding of the Concept of Tacit Knowledge – A Cognitive Approach

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***Abstract*—**Tacit knowledge has been one of the most discussed and contradictory concepts in the field of knowledge management since the mid 1990s. The concept is used relatively vaguely to refer to any type of information that is difficult to articulate, which has led to discussions about the original meaning of the concept (adopted from Polanyi's philosophy) and the nature of tacit knowing. It is proposed that the subject should be approached from the perspective of cognitive science in order to connect tacit knowledge to empirically studied cognitive phenomena. Some of the most important examples of tacit knowing presented by Polanyi are analyzed in order to trace the cognitive mechanisms of tacit knowing and to promote better understanding of the nature of tacit knowledge. The cognitive approach to Polanyi's theory reveals that the tacit/explicit typology of knowledge often presented in the knowledge management literature is not only artificial but totally opposite approach compared to Polanyi's thinking.

***Keywords*—**Cognitive science, explicit knowledge, knowledge management, tacit knowledge.

I. Introduction

MICHAEL Polanyi's epistemology has been a subject to considerable amount of interest in the field of contemporary management research. Particularly, the concept of tacit knowledge has become a common buzzword that is almost impossible to avoid seeing in the contemporary knowledge management (KM) literature. In the 1990's Polanyi's tacit knowledge became related to the widely supported claim that organizations can achieve competitive advantages by using effectively their unique knowledge (see e.g. [1]). Since then possible procedures for making tacit knowledge representable has been a widely discussed issue in the KM literature.

Polanyi made in his theory a distinction between two different kinds of awareness that involved different kinds of knowing; the content of *focal awareness* was conscious and thus subject to verbal description. However, according to Polanyi [2] focal (or 'explicit') knowledge was always based on tacit knowing in *subsidiary awareness*. Drawing from Polanyi, various authors have chosen an ontological position according to which there generally exist two types of knowledge, tacit knowledge and explicit knowledge (e.g. [3]-[5]). This interpretation has been claimed to be misleading, even opposite to Polanyi's thinking (see e.g. [6], [7]) According to the view that distinguishes tacit and explicit knowledge, explicit knowledge is usually defined straightforwardly as codified knowledge, easy to share in words and numbers [8]. However, defining the concept of *tacit* knowledge has proven to be extremely difficult task. That is probably why the attempts to define it are often bypassed in the KM literature by remarking that tacit knowledge is "knowledge difficult to articulate" (e.g. [9], [10]); the definition seems logical once the tacit-explicit distinction has been made and tacit knowledge becomes juxtaposed with articulate explicit knowledge.

However, according to the definition of tacit knowledge presented above *anything* difficult to represent instantly using language can be generalized to be 'tacit knowledge'. Thus, it seems that tacit knowledge has become a "warehouse" for any ambiguous or difficultly approachable mental or social phenomena in various scientific fields. The term 'tacit knowledge' nowadays has a large variety of meanings also in the KM literature [11], [12]. Very rare, if any, other scientific concept leaves the reader as puzzled about the innermost meaning of the concept as the concept of tacit knowledge.

Despite that the concept of knowledge has a heavy philosophical charge it is proposed that in order to understand human knowing and its tacit capacities the subject area should be approached from the perspective of cognitive sciences; the varied proposals of the exploitation of tacit knowledge lack firm grounding to real cognitive phenomena. Also, the traditional analysis of knowledge (i.e. knowledge seen as a justified true belief) is a rather stiff characterization to explain the knowledge on which human acting is based in the ever-changing environment that requires fast decisions and problem solving. Instead, knowledge is property of individual minds and the understanding of mind-brain architecture is becoming an increasingly important issue also for epistemology.

The problem of lack of cognitive perspective described above is considered to be problematic feature also in Polanyi's theory. In fact, one important reason for the abstruseness of Polanyi's theory is the lack of efforts to elucidate cognitive processes behind tacit knowing [13], [14]. It is, however, quite natural because cognitive sciences were only developing at the time when Polanyi developed his most important results. The fact that Polanyi's philosophical concepts have not been

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connected with studied cognitive mechanisms is one important reason why tacit knowing has been interpreted so many varying and inconsistent ways.

Instead of offering a clear explanation of the cognitive processes on which tacit knowing is dependent, Polanyi illustrated his theoretical principles of knowing with various examples. Thus, some of the most important examples that Polanyi used are analyzed in order to explore the core of tacit knowing from the perspective of cognitive science. The downside of this approach is that a few examples are not necessarily enough to describe extensively the whole phenomenon. However, even a few examples can offer valuable insights to the phenomenon promoting its understanding. Moreover, while the correct use of the concept of tacit knowledge can be (and has been) questioned in many scientific writings, it can be confidently claimed that tacit knowledge is being discussed here *in its original sense* since the focus is on the examples that Polanyi himself used.

The aim is to provide answers to three questions:

1. What is tacit knowledge like in a cognitive sense; on what kind of cognitive mechanisms tacit knowing is based?
2. How can Polanyi's claim that explicit knowledge is based on tacit knowledge be justified; what is the relation between tacit and explicit knowledge from the perspective of cognition?
3. What kind of epistemic contents (if any) tacit knowledge bears?

By setting Polanyi's theory into a wider cognitive and epistemic framework it is possible to gain better understanding of his theory generally and the concept of tacit knowledge specifically. It seems that this kind of cognitive extension of his theory has not been done before. However, it is necessary to answer the questions presented above before realistic models of management or explication of tacit knowledge can be developed.

In the next section Polanyi's philosophy is discussed briefly in order to introduce the core of his idea of tacit knowing. Three groups of examples of tacit knowing are then discussed in the sections III-V. Based on the analysis of these examples, the epistemic status of tacit knowledge is considered in the section VI. The conclusions are presented in the section VII.

II. Polanyi's Theory

The starting point of Polanyi's epistemology was his dissatisfaction with positivist philosophy of science and the epistemological account following from it. According to positivism genuine knowledge had to be verified by experience and scientific method. Sense data was considered to be the foundation of human knowledge, but logic was also seen as a valid tool for producing knowledge by deducing conclusions from the known facts. In this sense, not only knowledge itself had to be fully explicit but also the logical steps that led to it.

Polanyi [15] argued that positivism itself could not lead to genuine knowledge because scientific discoveries could not be credited to any purely analytical operation. He explained that the first step of any discovery or creative act was to see a problem. Knowing a problem was thus knowing something hidden; "it is an engrossing possession of incipient knowledge that passionately strives to validate itself." [16, pp. 131-132]. According to Polanyi [2], modern science was based on disjunction of objective and subjective and thus aimed to eliminate passionate and personal human appraisals from theories of science. Instead, Polanyi claimed that personal participation was included in every act of knowing. As he [2, p. viii] put it, "Into every act of knowing there enters a passionate contribution of the person knowing what is being known, and … this coefficient is no mere imperfection but a vital component of his knowledge."

Thus, in Polanyi's philosophy the knower is situated in the most fundamental position instead of what is being known; the knower does not simply pick up or see the meaning of knowledge but actively forms it by integrating his personal appraisals to the thing that is being known. Polanyi believed that the positivist demand that all subjectivity had to be eliminated from knowledge was impossible to fulfill, because there could not be knowing without the active involvement of a knower [13].

Unlike traditional epistemology, Polanyi's theory of knowledge stresses the process of knowing instead of its justification. Thus, the mental skills that cannot be formalized by language or the ones that escape the knower's focal attention are in the center of his analysis of knowing. He stresses that the embodied participation of the knowing subject is the most fundamental element of knowing. By placing the embodied activity at the center of human cognition Polanyi connects the knowing subject and that which is to be known instead of separating them as in modern philosophy traditionally has been done [17].

Polanyi [16, p. 147] argues that making sense of the world was about "relying on our tacit knowledge of impacts made by the world on our body and the complex responses of our body to these impacts". Thus, all knowledge has bodily roots because external objects are attended by being subsidiarily aware of things happening within the body. In this sense the body is not a mere passive physical object in the world but serves as an interface by which one comes to know the world through interaction. Therefore the formation of focal meaning is fundamentally bodily action.

Polanyi [2] presents a distinction between two kinds of awareness that is parallel to the distinction between tacit and explicit dimensions of knowing. *Focal awareness* concerns the object of conscious act, for example an external object or a propositional belief. *Subsidiary awareness* refers to the bodily basis on which the focal awareness operates; processes of subsidiary awareness provide the elements that the focal object consists of. Thus, tacit knowledge and tacit mental skills belong to subsidiary awareness whereas the articulate, or conscious, knowledge emerges to focal awareness.

Consequently, knowing agents can describe and construct rules for explicating what is in focal awareness.

However, as focal awareness is supported by subsidiary awareness, the explication of the contents of focal awareness remains always incomplete [18]. The thing the knower is focally aware of as a result of an act of knowing is formed subsidiarily of *tacit clues*, which enriches focal knowledge with personal coefficient [2]. Therefore the knowledge of the focally attended things is based on something more fundamental; explicit knowledge is based on tacit clues, or tacit knowledge. Moreover, in Polanyi's thinking this structure is present in every conscious act. Knowing agents end up having conscious (explicit) representations that are enabled by tacit processes and tacit particulars that the knower cannot define.

Since the main interest in the present context is in explaining why tacit knowledge is "tacit", the most important question is why the content of subsidiary awareness remains unspecified. Polanyi [19] presents two reasons for the tacitness of subsidiary particulars. First, *the difficulty of tracing the subsidiaries*, which means that the subject is "focally ignorant" of the subsidiaries; the subject knows only the joint meaning of the tacit clues but does not reach the clues themselves [20]. This explanation seems to refer directly to unconscious cognitive processes. Second, *logical sense deprivation*, which means that the subsidiary clues can be traced but if traced they become focal losing their subsidiary meaning and function. For example, a pianist playing his instrument focuses his attention on the piece of music that he is playing being only subsidiarily aware of the movements of his fingers. If he suddenly shifts his attention to the movements of his fingers, he gets confused and probably has to stop the playing [21].

As the example of a pianist already suggested, the two types of awareness are in Polanyi's theory mutually exclusive in the sense the subject cannot attend to both of the awareness at the same time. Thus, logical unspecifiability means that the tacit particulars of the performance might be focally known as such, but even in this case their *functional* meaning in the performance itself remains tacit.

Polanyi also distinguishes between two different types of tacit knowledge, particularly in the case of perception (e.g. in [22], [23]). First, *subliminal clues* that refer to the somatic events that cannot be observed directly. Second, *marginal clues* that can be observed directly, but do not become attended to because attention is directed to some other target. Polanyi further divided also marginal cues into two kinds [24]; besides what can be seen marginally externally (for example, in perception at the corner of the eye) knowing agents are influenced by internal marginal clues (for example memories). Thus, knowing agents tend to see things as they are used to see them, or supposed to see them. The types on unspecifiability and tacit clues are summarized in figure 1.

Although Polanyi analyzed the reasons of unspecifiability and the different types of tacit clues he did not offer a clear explanation of the cognitive processes on which tacit knowing is dependent. Instead, Polanyi illustrated his theoretical principles of knowing with various examples. There are three particularly important groups of examples in the sense that these examples repeat in his literature.

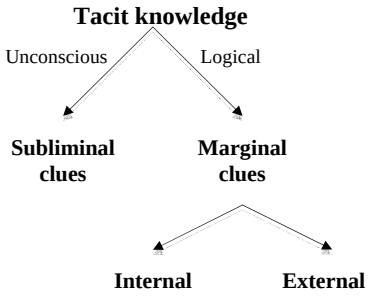

Fig. 1 Theoretical types of tacit knowledge as presented by Polanyi.

1. *Tacit knowing related to perception.*
   Polanyi found in perception a most useful example to elucidate the structure of tacit knowing and the idea of mental integration. For example, visual perception that happens seemingly very effortlessly is an act of integration of many clues to a focal perception of attended object. As Polanyi [19, p. 28] puts it, "I look at my right hand as I move it about in front of me, and I see a thousand rapidly changing clues as one single, unchanging object moving about at changing distances, presenting different sides at variable angles and in variable light. The integration is innumerable, rapidly changing particulars makes us see a real object in front of us."

2. *Tacit knowing related to emotional responses.*
   In *The Tacit Dimension* Polanyi [21] discusses a psychological experiment (conducted by Lazarus and McCleary [26]) in which the authors presented nonsense syllables to the subjects. Half of the syllables had been associated with a painful electric shock whereas the other half consisted of neutral control syllables. The authors found that the subjects were unable to recognize or identify the shock-causing syllables, but showed symptoms of anticipating the shock (measured with galvanic skin response) when a shock-syllable was presented—even when the exposure time of a presented syllable was too short for a conscious recognition. The authors concluded that "some kind of discrimination is made when the subject is unable to make a correct conscious discrimination." Polanyi claims that this experiment shows *most clearly* what is meant by saying that one can know more than one can tell. The main point in this group of examples is that one can acquire knowledge that affects or guides one's action but what cannot be specified; the knowing subject is

not fully aware of the nature of the knowledge he has nor necessarily even the fact that it affects his judgment. Instead, what the subject is aware of is some kind of feeling that there might be something special in a certain stimulus.

3. *Tacit knowing in skilful performances.*
There is nothing new in the claim that *knowing how* to do something is generally difficult to describe. Polanyi discussed about hidden rules that are not explicitly known to the actor himself for example in such performances as riding a bicycle [2], playing a piano [21] and using tools [23]. Thus, the third group of Polanyi's examples is essentially about motor skill learning.

Each of these groups of examples will now be discussed in its own section.

III. Tacit Knowledge in Perceptual Processes

Many of Polanyi's examples in group one discuss the problem of having at the center of the attention a constant, unambiguous perception of an object (focal awareness) that is dependent on clues to which one is not attending (subsidiary awareness). For example, "When looking at the stereo-image, we do see the separate pictures too; for we see the stereo-image only because we have a precise impression of the two pictures which contribute to it. But we must distinguish between the two kinds of seeing: we are focusing our attention on the stereo-image, while we see the two pictures only as they bear on the stereo-image. We don't look at these two in themselves, but see them as clues to their joint appearance in the stereo-image. It is their function to serve as clues. We may describe the situation by saying that we are focally aware of the stereo-image, by being subsidiarily aware of the two separate pictures … The seeing of two stereo-pictures as one spatial image is, indeed, irreversible in two senses. Firstly, it is difficult to find our way back to the clues in the two pictures, because they are hardly visible. And there are many other clues to seeing something, like memories and the feeling inside our eye muscles, which we either cannot trace or cannot experience in themselves at all; they are largely submerged, unspecifiable." [25, p. 800]

Perception in general refers to the acquisition and processing of sensory information in order to see, hear, taste or feel objects [27]. The main purpose of perception is to organize the continuously changing sensory input into stable, meaningful objects and recognize them.

It can be obviously questioned if the process of perception counts as a form of knowing at all since it seems in a sense a self-evident and passive process. However, perceiving things does not mean that they are perceived exactly as they are in the reality. For example, in visual perception a visual representation is constructed according to the type of data the receptors in our eyes are capable of recognizing. The brain then receives and analyses sensory signals, not the environment as such. Thus, perceiving does not mean mirroring reality in an objective way. Perception understood this way puts forward Polanyi's structure of knowing. Moreover, it is easy to agree that perception normally leads to justified beliefs about the external world. Thus, Polanyi considered perception as knowing even though he remarked that it was the simplest and impoverished form of it [21].

Despite that the heading of this section refers to perception in general, the main focus is on visual system because many of Polanyi's examples of perception concern visual system. However, the same general principles (related to tacit knowing) of perceptual processes concern also other sense modalities because each sensory system is organized on a rather similar plan [28].

All the sense modalities respond to a certain form of physical stimulus. In the case of visual system the form of physical energy is electromagnetic energy (light) [29]. Light passes through the eye and stimulates the color and brightness sensitive receptors in the retina. Electromagnetic energy is then converted to neural impulses and transmitted along optic nerves to the visual cortex specialized to the processing of visual information [28].

In the primary visual cortex the input information is segregated, among others, into color, form and movement, each of them represented by neurons sensitive to these attributes [30]. From the primary visual cortex the information goes to secondary areas that are specialized for processing these different features of the input. The processing of visual information continues from the secondary areas that have even more specific functions, such as object, face and body analysis [28]. Neural pathways of vision are finally connected to prefrontal cortex, the area generally related to working memory [31]. A conscious, coherent visual experience that that tells what there is and where is supposedly formed in working memory—the things that the subject is conscious of are the things that he is processing in the working memory [31].

In sum, visual system consists of different modules that analyze parallel different attributes of visual stimuli separately. The visual scene that a knowing agent is focally aware of is thus constructed of various components (such as shape, color, movement etc.) as Polanyi claimed. Refined visual information then gradually converges on its way towards working memory.

This crude and somewhat simplified description of the brain architecture related to visual perception reveals that the convergence of different type of information processed in the specialized modules is one of the key processes of comprehensive perception. This neuropsychological fact is well in unison with Polanyi's idea of "integrating clues into a comprehensive whole". At this stage of the process the clues are subliminal, because the processes are unconscious.

However, the most interesting question is, does this kind of anatomical architecture embody knowledge of any kind? It consists of interrelated, yet functionally independent, modules that receive data flows, process them and then send information forward to following modules.

Since the processes of the specialized areas are not random, it seems indispensable that these modules embody knowledge in order to determinate how a certain data flow is processed, even if the processing was mainly spontaneous sorting at the first stages. Let us briefly consider the function of some of the modules of the visual system in order to illustrate this idea.

Separation of objects: eye responds to stimulus pattern with a mosaic of millions of independent neural responses that code the amount of light falling on that particular area on the retina, and the first task is to determine which of these areas belong together [28]. The most important information for this process comes from color and texture; an abrupt change in color or texture is interpreted as a boundary between two regions [32]. This is why humans are able to see figures and their backgrounds; a stimulus that contains more than one region distinguished by a change in light or texture is normally seen as a figure and its background [33]. Thus, a change in color or texture *predicts* a border of two separate objects and is likely to be interpreted as such. Object's boundaries that are perceived in focal awareness are tacitly inferred based on changes in light and texture. These changes serve as cues of the boundaries of the object and the knowing subject is focally ignorant of them.

Tacit knowing in the case of separation of objects can thus be related to internal unconscious processes. However, Polanyi suggested that tacit knowing might also be based on environmental cues in which case the unspecified information is external to the knower. For example, the case of binocular vision that Polanyi discusses means that having two eyes (instead of one) makes it possible to see reality in three dimensions. Both eyes receive a slightly different view of the world and essentially these two views combined enable the perception of depth. The tacit process of combination of the two pictures into one richer version is also unconscious and internal. However, in addition to these binocular cues humans use also many external sources of information in order to assess depth. Some of this information is called monocular because its interpretation is possible using only one eye. For example, *interposition* is a depth clue occurring when an object blocks off the view of part of another object giving information that the occluded object is farther away [33]. *Linear perspective* is another clue of depth; it is present when two parallel lines pointing directly away seem progressively closer together as they recede into the distance (e.g. railway tracks). Also *shading* (see e.g. [34], [35]) and *familiar size* (knowledge of the actual size of a distant object, see e.g. [36]) have been shown to be powerful monocular depth clues. Thus, monocular clues are external from the knower's perspective but provide rich information that is tacitly assessed in a process of perception.

Consequently, the world is perceived unaware of the calculations and tacit inferences that construct the perception. The cognitive perspective is thus in tune with Polanyi's claim that we observe external facts without an exhaustive formal argument and without a capability of explicitly stating how it gets done.

Recognition of perceived object amounts to assigning an object to a category or to a particular instance (for example in a case of recognizing a face). For that the constructed representation has to be compared to object representations stored in long-term memory [33]. However, perception is not a process driven solely by input information from the senses (bottom-up processes). Individual knowledge, expectations and contextual factors (top-down processes) have been shown to affect considerable to human perception. For example, confronting objects in places we expect to see them makes it easier and faster to recognize them [37]. Therefore it is easier to recognize that an object is a piece of soap based on the fact that it is on the sink. Thus, interpretation of perceptual input depends on pre-existing, organized knowledge structures that provide *predictions* of "what should be there" based on the previous experiences (internal marginal clues in Polanyi's terms).

From the viewpoint of knowing recognition is particularly important stage because it enables the access to semantic knowledge and individual episodic memories concerning perceived object. In this sense recognition assigns meaning to percept and enables to retrieve conceptual information concerning the recognized object. Thus, object recognition is a point of confluence of in which personal aspects blend with information predominantly dependent on physiological structures and functions.

What then is tacit knowledge involved in the perceptual processes? According to Kolb and Whishaw [28] single neurons are coded to detect certain features from the visual input. Consequently, in the lowest level tacit knowing can be viewed as scanning for special features of stimuli and passing sorted information on to the more specialized areas. Perception is also affected by both internal marginal clues (prior beliefs and expectations) and external marginal clues (e.g. monocular clues) that support the formation of unambiguous interpretation. Also, tacit knowing includes the convergence of different type of visual information, which culminates in the focal representation in the working memory. Only at this stage it is possible to explicate what has been perceived.

IV. Tacit Knowledge Related to Emotional Responses

Polanyi [38] discusses various psychological experiments (e.g. [39], [40]) that are practically analogous to the Lazarus and McCleary's [25] experiment described earlier. The majority of these examples can be summed up in the following findings made by the authors of the experiments:

- The actual experiments were preceded by a conditioning phase during which some of the stimuli were systematically paired with an electric shock.
- In the actual experiments the subjects were unable to identify the shock-causing stimuli, but they showed physiological symptoms of anticipating the

shock whenever such a shock-causing stimulus was presented—even when the exposure time of a presented stimulus was too short for conscious recognition (see e.g. [25]).
- The subjects clearly avoided actions that caused the shock, but on questioning it appeared that they were not aware of doing it (e.g. [39]).

This group of examples can be considered particularly important, because Polanyi remarks that these experiments show "the principal mechanism by which knowledge is tacitly acquired" [21, p. 7].

Unconscious perception and implicit perception are other important mental phenomena related to subliminal perception. In fact, they are sometimes treated as synonyms for subliminal perception (e.g. [41]). Yet implicit or unconscious perception refers rather to a situation where a stimulus does not enter to conscious awareness because attention is directed to somewhere else (for example, attention may be directed to reading a text while certain events in the environment are processed unconsciously). Polanyi would probably call this kind of environmental information marginal tacit knowledge. Subliminal perception, however, refers to a situation in which the stimulus is presented too briefly for conscious perception, even if subject attends to it. In this sense subliminal perception is a narrower phenomenon than unconscious or implicit perception. Yet the fundamental principle concerning also unconscious and implicit perception is the same: the brain is capable of detecting and assessing stimuli below the level of conscious detection. Support for this claim has come from various authors (e.g. [42], [43]).

To be precise, subliminal perception as such does not seem to differ much from the basic perceptual process discussed in the previous section. Subliminal perception includes the early stages of perception but lacks proper recognition of the processed stimuli. However, this is not the most important aspect of the phenomenon that Polanyi describes. Instead, he addresses the fact that even without a correct, conscious recognition the stimulus gets registered and assessed by the nervous system. Polanyi [21] explains that even though the subjects did not recognize, for example, the distinction between shock-causing syllables and neutral syllables, they became aware of facing a shock syllable *based on the apprehension it evoked in them*. The unrecognized sight of a shock-causing stimulus made the subjects somehow aware of its presence.

The experiments that Polanyi refers seem to be essentially about classical conditioning; a neutral stimulus is presented along with a stimulus of some significance. The neutral stimulus is neutral in a sense that it does not produce a clear behavioral response in the subjects. Instead, the significant stimulus elicits automatically a reflexive response (such as mild sweating or changes in heart rate). After sufficient amount of repetitions of pairing the stimuli the neutral stimulus (even when presented alone) begins to elicit physiological responses equivalent with the responses caused by the significant stimulus. This passive learning process thus culminates in the formation of association between the neutral and the significant stimulus.

In these experiments the case was to associate an *unpleasant* stimulus with a neutral one; the subjects confronted unpleasant consequences of certain stimuli. From the evolutionary perspective something unpleasant refers to something potentially dangerous. This kind of conditioning is also known as *fear-conditioning*. According to Phelps [44], a typical fear-conditioning paradigm in humans involves presenting a neutral stimulus and pairing it with an aversive stimulus. An aversive stimulus automatically elicits physiological responses related to stress or fear, for example arousal in autonomic nervous system [45].

Although Polanyi's examples of subliminal perception are mostly related to the fear-conditioning paradigm it can be assumed that tacit knowing can be generalized to refer nervous system's ability to form associations to significant objects/events and manifest this knowledge via emotional system. In these particular examples bodily responses are emphasized as warning signals (predictions of *negative* consequences of certain stimuli), but Polanyi [21] wrote also about signals and cues that guide humans into right direction or "towards success" (predictions of *positive* consequences).

The emotional system provides predictive information what is advantageous and what is disadvantageous to the organism based on its previous experiences. As Damasio [45, p. 55] puts it, "Emotions are inseparable from the idea of reward or punishment, of pleasure or pain, of approach or withdrawal, of personal advantage or disadvantage." It is important to take into consideration that subliminal perception is only a peculiar instance of the functioning of the emotional system; emotional responses occur also during conscious perceptions. Subliminal perception, however, shows that no conscious representation of the association is needed in order to execute adequate emotional responses.

Following Damasio's [45] definition, emotions are complicated collections of chemical and neural responses that have some regulatory function that aims to creation of advantageous circumstances from the organism's perspective (e.g. fear prepares to retreat or escape). The most important function of emotions is therefore to produce a specific response in certain situations. Therefore emotional responses cause profound changes in the body and in the brain. The collection of these changes is a basis for neural patterns that eventually may become conscious feelings of emotions [45].

As organisms develop and interact they gain factual and emotional experiences with different objects and situations associating originally emotionally neutral things with naturally defined emotions [45]. However, Damasio stresses that virtually every perceived or recalled representation is accompanied by emotional response.

According to Ledoux [31], a neural association between two stimuli is possible only if there is a neural structure that receives information about both of the stimuli. In addition, there has to be a mechanism by which the association is

possible in the point of convergence. Findings of cognitive neuroscience have shown that certain brain areas are particularly important for emotional responses. Moreover, brain-imaging studies indicate activation of the amygdala (subcortical brain structure in both temporal lobes) during fear conditioning and later in response to the conditioned stimulus (e.g. [44], [46]) suggesting that amygdala has an important role in emotional processing. It monitors sensory inputs and triggers emotional responses related to fear and defense in the case of an aversive input.

Patients suffering from damage in amygdala fail to show normal physiological responses that healthy subjects show in fear conditioning experiments [44]. These subjects, however, may have a good cognitive understanding of the situation. Therefore they understand (in a rational sense) the relation between the neutral stimulus and the aversive event. However, the amygdala responds to significant stimulus automatically prior to cognitive awareness [47], [48]. Pure rational calculations without emotional information about the past experiences would most certainly make humans very ineffective. Moreover, Anderson and Phelps' [49] study suggests the amygdala can modulate sensory input and attention by increasing its activation in the presence of significant information, which ensures that emotional, thus important, stimuli get requisite amount of attention.

The significance of emotions does not restrict only to extreme behaviors such as escape or attack. Damasio [50] has addressed the significance of emotional information to human decision-making; our everyday decisions require predictions what will be advantageous or disadvantageous to us in different time spans. According to Damasio's *somatic marker hypothesis* experienced life events are marked in the brain by emotional system; the somatic consequences (changes in the body state) of every event are stored in order to be able to reproduce a copy of a corresponding somatic state next time when the organism is approaching the same (or same kind of) event. Thus, a reproduction of a somatic state can be seen as an emotional information based on previous learned experiences that has a potential to affect cognitive processing by favoring or suppressing somatically marked alternatives in cognitive processing without time-consuming, rational calculations (for example in complex decision-making). Support for Damasio's theory has come from various authors (e.g. [51], [52]).

Still, it is obvious that emotions cannot substitute reason. Damasio [50] stresses that emotions assist reasoning by pointing it where it should operate based on previous experiences; a relatively dynamic, overlapping use of these systems is probably the reason what makes humans cognitively very capable compared to other animals.

To be precise, emotion per se cannot be considered as tacit knowledge but rather as a manifestation of tacit knowledge. The source of the emotion in Polanyi's examples is related to the fact that two events have occurred sufficiently in parallel in the past. Tacit knowledge itself seems to be related to associations between objects/situations and advantageous/disadvantageous outcomes formed in interactions with them.

In sum, associative learning is an important mechanism to acquire knowledge about the world. It is a mechanism that predicts good/bad consequences or events that are likely to happen. Although Polanyi did not present extensive considerations about emotions in his theory, it seems that he was aware of the importance of automatic bodily mechanisms for human cognition. The most essential feature of associative learning mechanism in this context is that one does not have to be aware of important associations in order to be able to form them [53]. That is probably why such knowledge remains tacit.

V. Tacit Knowledge in Skill Learning

The third group of Polanyi's examples concerns motor skill learning. Polanyi used, among others, examples of riding a bicycle [2], playing a piano [21] and using tools [23] in order to describe how skillful actions are performed by relying on the coordination of muscular acts; one is aware of them only in terms of the performance but not aware of them in themselves. As Polanyi [26, p. 3] explains, "when we perform a skill, we attend focally to its outcome, while being aware subsidiarily of the several moves we co-ordinate to this effect."

Skill learning means a gradual improvement of performance with practice that generalizes to a range of stimuli within a domain of processing [54]. In the field of psychology motor skills are related to implicit memory that is often contrasted with explicit memory. Graf and Schacter [55, p. 501] define the distinction between these two memory systems in a following way: "Explicit memory is revealed when performance on a task requires conscious recollection of previous experiences … Implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection."

The strongest evidence to justify this distinction is the consistent finding that most amnesic patients have no difficulty is motor skill learning and performance although they generally perform poorly in explicit memory tasks. Explicit memory is generally considered to contain fact-based semantic memories and episodic memories whereas implicit memory is defined to be nonintentional and unconscious type of memory [28].

One important difference between implicit and explicit memories-based knowledge is the way the received data is encoded and stored. Explicit memories depend on conceptually driven processing, in which the subject reorganizes the data in order to store it. Instead, encoding implicit information depends simply on receiving the sensory information without a need to manipulate it by "higher" (conscious) cognitive processes [28]. Thus, implicit learning refers to the process of acquisition of complex information typically in a non-conscious way, which leads to learning of this information without complete articulate knowledge of

what has been learned [56].

From the perspective of neuroscience motor skill learning seems to be an integrative product of various neural mechanisms, each contributing to a different aspect of learning [57]. Several lines of evidence, such as functional imaging studies, suggest that the motor cortex, the basal ganglia and the cerebellum are particularly important brain regions for motor skill learning. According to the contemporary view on motor skills, motor cortex is organized for the control of movements that require the coordinated action of many muscles in different combinations [28]. This view suggests that humans have a repertoire of movement categories in the motor cortex [59].

One important idea emerging in the field of motor skill learning research is that basal ganglia teaches the cortex through a certain type of trial-and-error learning [58], [60]. This means that messages from the motor cortex are optimized in terms of their reward value and accuracy, and repetition of the successful behavior leads to the reinforcement of corresponding motor patterns [58].

Feedback is thus a necessary element for any motor skill learning to occur through reinforcement of a motor pattern. In this context so called intrinsic feedback has an essential role; it refers to sensory information received by the actor as a direct result of producing a movement [61]. Intrinsic information can come from the sources outside the body (e.g. visual feedback) or sources inside the body (from muscles, joints or the sense of balance). Intrinsic feedback is important for attempts at replicating successful responses because when a desired result is achieved the actor attempts to repeat it [61]. The resulting motor pattern is then constantly updated in the following performances [53]. Due to the skill learning mechanism outlined above it seems that humans do not have conscious rules of how to do something, but rather what they are trying to do.

Behavioral, brain imaging and cognitive neuropsychological studies provide evidence that motor skill learning is a complex and staged process. However, in the present context it is essential to understand that there cannot be any type of learning without some kind of structure where experiences can be stored and recollected. Practice results in a gradually evolving and specific representation of the trained sequence of movements in human motor system. More specifically, practice results in functional and structural neural plasticity that leads to the construction of new motor maps in the brain [62]. Behaviorally this can be seen as an elimination of extraneous movements and effective coordination of muscles to act as a single functional unit [62]. As opposed to declarative forms of memory, these changes are known to evolve slowly, requiring many repetitions over several training sessions.

Generally speaking, and specifically from the evolutionary perspective, motor skill learning leads to automatic behaviors. Wheatley and Wegner [63] define automaticity as actions that occur efficiently and without the need of conscious guidance. A certain skill becomes more automatic through repetition, and finally it requires hardly any conscious monitoring; if all actions required conscious thought, there would not be time to anything else than planning the next step [63].

The epistemic value of this kind of know-how has not been questioned in the KM literature. It seems to be a very common way generally in the literature concerning knowledge to divide knowing to two categories, *knowing that* and *knowing how*, following Ryle's [64] distinction. Also, in the field of psychology procedural knowledge is presented alongside with declarative knowledge. Indeed, the fact that someone can act skillfully seems to necessitate some kind of knowledge despite the subject's inability to explain or even articulate that skill.

But how can it be justified that skills have real epistemic content? A skill means that there is a plan how to handle a certain situation, and when the decision to use the skill is made behavior is automatically channeled into that plan [65]. Repetition of certain act develops the behavior because actions that lead to good or at least satisfactory results get reinforced. In a biological level the reinforcement can be understood as neural changes that lead to development of new motor maps.

The resulting skill embodies knowledge because its components are stored to neural structures based on the observation of their positive outcome. It is knowledge about the adequacy of a certain motor response to a certain stimulus or a situation. Thus, the knowledge that is embodied in certain skill seems to be a link between a certain situation (or stimulus), a motor response (or a sequence of motor responses) and a satisfactory outcome. Again, in the present context the most important question is, why that knowledge remains tacit.

Psychological evidence suggests that implicit learning is not dependent on higher cognitive processes. There is no need to process the procedure being learned consciously. Moreover, motor skill learning does not presuppose any use of language, which differentiates it from learning of many forms of declarative knowledge. As the evolutional motivation of motor skills is to know how to act in a certain situation when confronting it, that knowledge need not be represented in a propositional form. From the perspective of performing a skill it is absolutely irrelevant whether the actor is able to verbalize that skill.

VI. The Epistemic Status of Tacit Knowledge

According to the analysis of the first two groups of examples the focus of Polanyi's epistemology is essentially on the process of formation of the contents of focal awareness. They explain the basic principles of the creation of perceptual knowledge of the environment (Group one) and the following possible intuitive knowledge that leads to approach and retreat behaviors (Group two). Following from this, it seems that tacit knowledge and the processes related to it in the first two groups of examples are essentially about the *formation of focal belief*. Interestingly, the traditional analysis of knowledge only starts from the belief and is primarily

concerned with questions related to the truthfulness and justification of the beliefs. Polanyi's theory of knowledge precedes the traditional approach in this sense; the most fundamental part of Polanyi's epistemology concerns tacit knowing situated in subsidiary awareness, which describes first and foremost *how* humans arrive at their conscious beliefs or representations.

Obviously the evolutionary function of these processes is not to create focal beliefs but has been motivated purely by adaptation and survival. Moreover, perceptual, emotional and automated motor processes are functions that are not typical only to humans, but also appear widely in other species. All mammalian sensory systems follow the same basic principles on their anatomy, function and chemistry [66]. Also, different forms of associative learning appear and have been studied in many animals. Thus, the evolutionary roots of these processes go much further back in time compared to higher processes of consciousness, such as the use natural language typical only to humans.

Human intelligent behavior should be thus viewed as being organized in a hierarchical way out of older neural modules, each of which had evolved programs for particular functions [67]. Therefore also from this perspective unconscious mental processes can be considered as the epistemic foundations on which emerging explicit operations are based. However, probably due to the introspective obviousness of conscious knowledge it has been traditionally given the epistemic priority compared to the tacit processes [68].

From these perspectives it is rather uncomplicated to accept one of the strongest of Polanyi's claims: explicit knowing is based on tacit knowing and thus cannot be fully justified by analytical argumentation. In this sense Polanyi's theory of knowledge refers to a form of naturalized epistemology, according to which epistemic status of a belief state depends on psychological processes that generate and sustain it [70]. According to this view natural cognitive and physiological processes involved in the process of knowing cannot be bypassed in an analysis of knowledge. However, Polanyi's epistemology represents a quite light form of naturalism because, as most of the philosophical theories of knowledge, naturalist theories tend to deal with the question of justification by describing processes that are generally reliable in generating epistemically virtuous mental states (see e.g. [71]). However, Polanyi was not particularly interested in the norms that justify human knowledge. Instead, he stressed in general the importance of confidence in human cognitive capacities in understanding reality.

Polanyi's argument of the fundamental position of tacit knowledge in all knowing is supported from the cognitive perspective. This means that the tacit/explicit typology of knowledge presented in many writings of KM literature is not only artificial, but also totally opposite approach compared to Polanyi's thinking. Polanyi's main point was that no cognitive judgment can ever be made wholly explicit—he did not say that there generally exist two types of knowledge.

Moreover, in the KM literature it has been suggested that it is important to identify the subtypes of tacit knowledge in order to be able to better articulate or explicate tacit knowledge (see e.g. [72], [73]). Some of these subtypes are claimed to be for example intuitions, beliefs and mental models. However, in Polanyi's terms, what humans are able to describe verbally is the contents of focal awareness. From this perspective it seems problematic to claim that for example intuition is a subtype of tacit knowledge. Intuition is usually defined to be some kind of direct knowing without a formal argument (e.g. [72]). Indeed, tacit knowledge would be the argument, but it cannot be reached. What can be reached instead is the focal impression (that is, the intuitive feeling) that is only the conscious product or a reflection of tacit knowledge and tacit processes. Thus, although intuition is a manifestation of tacit cognitive powers, tacit knowledge itself remains unarticulated. In this sense intuitions, beliefs or mental models are not subtypes of tacit knowledge. If they were, even more fundamental form of knowledge than tacit knowledge would be logically necessary to explain how these "subtypes" are formed.

VII. Conclusions

Cognitive mechanisms that make tacit knowledge tacit are based on a learning that is not dependent on subject's cognitive awareness of what is being learned, but essentially about automatic reinforcement/weakening of certain behaviors based on the received feedback. Thus, these processes are inductive and predictive by their nature.

From the cognitive perspective the structure of knowing that Polanyi presented seems justified; if explicit knowledge is considered to be justified belief, and tacit knowing refers to the process of forming that belief, in this sense tacit knowledge indeed precedes explicit knowledge as Polanyi claimed. The priority of tacit knowledge can be justified also in the sense that cognitive processes related to tacit knowing are evolutionally more fundamental than processes of 'explicit knowing' that are related to the use of language.

According to the traditional analysis of knowledge, tacit knowledge does not fulfill the requirements of knowledge; tacit knowledge is not necessarily justifiable (because the knowing subject might be focally ignorant of it) or true (because it is inductive by its nature). Tacit knowledge does not even include anything comparable to a conscious belief but is rather related to the unconscious belief-forming processes and to learned automatic responses to certain type of stimuli.

However, although tacit knowledge is inductive and predictive by its nature, it still embodies epistemic content. Tacit knowledge has its personal justification based on experiences that have produced neural changes that affect behavior in a purposeful way. It is essentially bodily knowledge as Polanyi proposed.

Although the vast majority of authors in the field of KM refer to Polanyi agreeing that the concept of tacit knowledge comes originally from his epistemology, very few of them

seem to base their understanding of the concept on Polanyi's philosophy. In the KM literature tacit knowledge is often related to context specific knowhow or expertise. It is important to bear in mind that Polanyi's analysis concerns *all the levels of cognition*. Therefore the structure of two kinds of awareness enters into all conscious acts from perception to complex problem solving.

Although the "lower level" tacit processes discussed here are probably not the primary interest in the KM field, the aim has been to promote better understanding of the concept of tacit knowledge. If we want to understand what tacit knowing is about it is essential to begin the endeavor from the very roots of the phenomenon.

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REFERENCES

[1] J. Spender, "Competitive Advantage from Tacit Knowledge?" In B. Moingeon, A. Edmondson, (eds.). *Organizational Learning and Competitive Advantage*. London: Sage Publications Ltd, 1996, pp. 56-73
[2] M. Polanyi, *Personal Knowledge–Towards a Post-Critical Philosophy*. Chicago: University of Chicago Press, 1958.
[3] I. Nonaka, R. Toyama, N. Konno, "SECI, *ba* and leadership: A unified model of dynamic knowledge creation. In I. Nonaka and D. Teece (eds.), *Managing Industrial Knowledge: Creation, Transfer and Utilization.* London: Sage Publications, 2001.
[4] R. Herschel, H. Nemati, D. Steiger, "Tacit to explicit knowledge conversion: knowledge exchange protocols". *Journal of Knowledge Management*, vol. 5, pp. 107-116, 2001.
[5] C. Kikoski, D. Kikoski, *The Inquiring Organization–Tacit Knowledge, Conversation, and Knowledge Creation: Skills for 21st-Century Organizations*. Portsmouth: Greenwood Publishing Group, 2001.
[6] K. Grant, "Tacit knowledge revisited–We can still learn from Polanyi", *The Electronic Journal of knowledge Management*, vol. 5, pp. 173-180, 2007.
[7] T. Wilson, "The nonsense of 'knowledge management'", *Information Research*, vol. 5, 2002.
[8] I. Nonaka, H. Takeuchi, *The Knowledge-Creating Company*. New York: Oxford University Press, 1995.
[9] P. Baumard, *Tacit Knowledge in Organizations*. London: Sage Publications, 1999.
[10] M. Hansen, N. Nohria, T. Tierney, "What's your strategy for managing knowledge?" *Harward Business Review*, March-April, pp. 106-116, 1999.
[11] V. Ambrosini, C. Bowman, "Tacit knowledge: some suggestions for operationalization. *Journal of Management Studies*, vol. 38, pp. 811-829, 2001.
[12] S. Gourlay, "'Tacit knowledge': the variety of meanings in empirical research". *In proc 5th European Conference on Organizational Knowledge, Learning and Capabilities* 2004, Innsbruck, Austria, 2004.
[13] E. Webb, *Philosophers Of Consciousness*, Seattle: University of Washington Press, 1988.
[14] W. Gulick, "Polanyi's scholary influence: A review article. *Tradition & Discovery*, vol. 16, pp. 11-23, 2005.
[15] M. Polanyi, *Science, Faith and Society*. Chicago: University of Chicago Press, 1964.
[16] M. Polanyi, *Knowing and Being*. London: Routledge & Kegan Paul, 1969.
[17] J. Gill, *The Tacit Mode–Michael Polanyi's postmodern Philosophy*. Alabany: State University of New York Press, 2000.
[18] S. Jha, *Reconsidering Michael Polanyi's Philosophy*. Pittsburgh: University of Pittsburgh Press, 2002.
[19] M. Polanyi, "Logic and psychology". *American Psychologist*, vol. 23, pp. 27-43, 1968.
[20] M. Polanyi, *Study of Man*. Chicago: University of Chicago Press, 1958.
[21] M. Polanyi, *The Tacit Dimension*. Garden City: Doubleday & Company, 1966.
[22] M. Polanyi, "On body and mind", *The New Scholasticism*, vol 43, pp. 195-204, 1969.
[23] M. Polanyi, "The logic of tacit inference", *Philosophy: The Journal of The royal Institute of Philosophy*, vol. 41, pp. 1-19, 1966.
[24] H. Prosch, *Michael Polanyi: A Critical Exposition*. Albany: State University of New York Press, 1986.
[25] R. Lazarus, R. McCleary, "Autonomic Discrimination without Awareness: A Study of Subception". *Psychological Review*, vol. 58, pp. 113-122, 1951.
[26] M. Polanyi, "The structure of consciousness", *Brain*, vol. 88, pp. 799-810, 1965.
[27] R. Sekuler, R. Blake, *Perception* (4th ed.), New York: McGraw-Hill, 2002.
[28] B. Kolb, I. Whishaw, *Fundamentals of Human Neuropsychology* (6th ed.), New York: Worth Publishers, 2009.
[29] M. Eysenck, T. Keane, *Cognitive Psychology* (5th ed.). New York: Psychology Press, 2005.
[30] A. Paivio, *Mind and Its Evolution–A Dual Coding Theoretical Approach*, New Jersey: Lawrence Erlbaum Associates, 2007.
[31] J. Ledoux, *Synaptic Self: How Our Brains Become Who We Are*, New York: Viking Peguin, 2002.
[32] P. Zimbardo, M. McDermott, J. Jansz, N. Metaal, *Psychology: A European Text*, London: Longman, 1995.
[33] R. Atkinson, R. Atkinson, E. Smith, D. Bem, S. Nolen-Hoeksema, *Hilgard's Introduction to Psychology* (13th ed.), Orlando: Harcourt Brace, 2000.
[34] V. Ramachandran, "Perception of shape from shading", *Nature*, vol. 331, pp. 163-166, 1988.
[35] D. Kersten, P. Mamassian, D. Knill, "Moving cast shadows induce apparent motion in depth", *Perception*, vol. 26, pp. 171-192, 1997.
[36] W. Ittelson, "Size as a cue to distance: Static localization". *American Journal of Psychology*, vol. 64, 54-67, 1951.
[37] I. Biederman, "Higher level vision". In D. Osherson, S. Kosslyn, J. Hollerbach (eds.), *An Invitation to Cognitive Science: Visual Cognition and Action.* Cambridge: MIT Press, 1990.
[38] M. Polanyi, "*Tacit knowing: its bearing on some problems of philosophy*", Reviews on Modern Physics, vol. 34, pp. 601-616, 1962.
[39] J. Lacey, R. Smith, "Conditioning and generalization of unconscious anxiety", *Science*, vol. 120, pp. 1045-1052, 1954.
[40] G. Razran, "The observable unconscious and the inferable conscious in current Soviet psychophysiology: Interoceptive conditioning, semantic conditioning, and the orienting reflex", *Psychological Review* vol. 68, pp. 81–150, 1961
[41] R. Bornstein, "Source Amnesia, Misattribution, and the Power of Unconscious Perceptions and Memories". *Psychoanalytic Psychology*, vol. 16, pp. 155-178, 1999.
[42] P. Merikele, D. Smilek, D. Eastwood, "Perception without Awareness: Perspectives from Cognitive Psychology". *Cognition*, vol. 79, pp. 115-134, 2001.
[43] J. Bruner, "Another Look at New Look 1". *American Psychologist*, vol. 47, pp. 780-783, 1992.
[44] E. Phelps, "The interaction of emotion and cognition: the relation between the human amygdala and cognitive awareness". In R. Hassin, J. Uleman, J. Bargh (Eds.), *The New Unconscious*. New York: Oxford University Press, 2005.
[45] A. Damasio, *The Feeling of What Happens: Body Emotion in The Making of Consciousness.* San Diego: Harcourt, 1999.
[46] K. LaBar, C. Gatenby, J. Gore, E. Phelps, "Human amygdala activation during conditioned fear acquisition and extinction: A mixed-trial fMRI study". *Neuron*, vol. 20, pp. 937-945, 1998.
[47] H. Breiter, H. Etcoff, P. Whalen, W. Kennedy, S. Rauch, R. Buckner, M. Straus, S. Hyman, B. Rosen, "Response and habituation of human amygdala during visual processing of facial expression. *Neuron*, vol. 17, pp. 875-887, 1996.
[48] P. Whalen, S. Rauch, N. Etcoff, S. McInerney, M. Lee, M. Jenike, "Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge". *Journal of Neuroscience*, vol. 18, pp. 411-418, 1998.

[49] A. Anderson, E. Phelps, "Lesions of the human amygdala impair enhanced perception of emotionally salient events". *Nature*, vol. 411, pp. 305-309, 1999.
[50] A. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Putnam Publishing, 1994.
[51] S. Carter, M. Smith Pasqualini, "Stronger autonomic response accompanies better learning: A test of Damasio's somatic marker hypothesis. *Cognition and Emotion*, vol. 18, pp. 901-911, 2004.
[52] A. Bechara, D. Tranel, H. Damasio, "Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain*, vol. 123, pp. 2189-2202, 2000.
[53] C. Frith, *Making Up The Mind–How the Brain Creates Our Mental World*, Malden: Blackwell Publishing, 2007.
[54] R. Poldrack, V. Prabakharan, C. Seger, J. Gabrieli, "Striatal activation during cognitive skill learning". *Neuropsychology*, vol. 13, pp. 564-574, 1999.
[55] P. Graf, D. Schacter, "Implicit and explicit memory for new associations in normal and amnestic subjects. *Journal of Experimental Psychology: Learning, Memory and Cognition*, vol. 11, pp. 501-518, 1985.
[56] C. Seger, "Implicit learning", *Psychological Bulletin*, vol. 115, pp. 163-196, 1994.
[57] O. Hikosaka, K. Nakamura, K. Sakai, H. Nakahara, "Central mechanisms of motor skill learning". *Current Opinion in Neurobiology*, vol. 12, pp. 217-222, 2002.
[58] A. Graybiel, "The basal ganglia: learning new tricks and loving it", *Current Opinion In Neurobiology*, vol. 15, pp. 638-644, 2005.
[59] M. Graziano, "The organization of behavioral repertoire in motor cortex", *Annual Review of Neuroscience*, vol. 29, pp. 105–134, 2006.
[60] K. Doya, "Complementary roles of basal ganglia and cerebellum in learning and motor control", *Current Opinion in Neurobiology*, vol. 10, pp. 732–739, 2000.
[61] R. Schmidt, C. Wrisberg, *Motor Learning and Performance*. (4th ed.) Champaign: Human Kinetics, 2008.
[62] L. Ungerleider, J. Doyon, A. Karni, "Imaging brain plasticity during motor skill learning". *Neurobiology of Learning and Memory*, vol. 78**,** pp. 553–564, 2002.
[63] T. Wheatley, D. Wenger, "Automacity of action", In N. Smelser, P. Baltes, *International Encyclopedia of Social & Behavioral Sciences*, Oxford: Elsevier, 2001.
[64] G. Ryle, *The Concept of Mind*, London: Hutchinson, 1949.
[65] J. Pollock, J. Cruz, *Contemporary Theories of Knowledge*. Lanham: Rowman and Littlefield Publishers Inc., 1999.
[66] J. Kalat, *Biological Psychology* (7th ed.), Toronto: Wadsworth, 2001.
[67] P. Rozin, "The evolution of intelligence and access to the cognitive unconscious", *Progress in Psychobiology and Physiological Psychology*, vol. 6, pp. 245-280, 1976.
[68] A. Reber, *Implicit Learning and Tacit Knowledge*. New York: Oxford University Press, 1993.
[69] F. Krick, K. Koch, *The Astonishing Hypothesis–The Scientific Search for the Soul*. London: Simon & Schuster, 1994.
[70] P. Kitcher, "The naturalist return", *The Philosophical Review*, vol. 101, pp. 53-114, 1992.
[71] A. Goldman, *Epistemology and Cognition*. Cambridge: Harvard University Press, 1986.
[72] R. McAdam, B. Mason, J. McCrory, "Exploring the dichotomies within the tacit knowledge literature: towards a process of tacit knowing in organizations", *Journal of Knowledge Management*, vol. 11, pp. 43-59, 2007.
[73] T. Haldin-Herrgard, "Mapping tacit knowledge with Epitomes", *Systèmes d'Information et Management*, vol. 2, pp. 93-111, 2003.