Chapter 2
Body and Mind—A Historical Perspective

What is Matter? Never mind.
What is Mind? No matter.

Punch, 1855

What is the relation between the body and the mind? Is the body just a mechanical container for the immaterial mind as proposed by dualists such as Descartes? Or is it the computational physical input-output interface to the world, as functionalist philosophers and many cognitive scientists today would argue? Or are our cognitive processes strongly dependent on the body as the proponents of the embodied approach? Are in fact 'body' and 'mind' just two sides of the same coin? These questions do not have any clear answers yet, but philosophers and scientists have been discussing these issues for a very long time with very different outcomes. As seen in the following chapters, this discussion is still a "hot topic" in contemporary cognitive science, but in order to discuss these questions accurately, it is important to review their historical context, which is the overall goal of this background chapter.

More precisely, this chapter has four interrelated aims. Firstly, the historical background for the 'study of mind' is outlined in a chronological way, beginning from its philosophical roots to the foundation of cognitive science and the computational paradigm. I believe that for any science, in particular an interdisciplinary one such as cognitive science, it is of great significance to know what has happened in the past in order to understand the present, and then hopefully avoid repeating mistakes and misunderstandings that have already been made. The second aim is to explain why the idea of *computationalism* became the dominant position within cognitive science at the expense of alternative approaches. However, it should be noted that there is neither enough space nor time to offer the whole story (cf. e.g. [1–7], for more complete overviews of the history of cognitive science and AI), and therefore I present a somewhat simplified view with a focus on the key concepts. Then a glimpse of the wide source of theories of agent-environment interactions from which modern cognitive science may still have much to gain is presented, re-evaluating and possibly incorporating some of these 'old' ideas. The final aim is to situate the resulting

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framework for the embodied nature of socially interactive cognition within its historical context, and to some extent, to *motivate* it. Thus, below follows my story of the ebb and flow of embodiment throughout the history of theories of the mind.

2.1 The Roots of Dualism—From Plato to Descartes

The philosophical roots of cognitive science date back to the old Greeks, and Gardner [6], for example, pointed out that cognitive science has a long past but a short history. According to Gardner, the Greeks devised the mathematical inventions of logic and geometry and consequently, the notion that all human reasoning could be a sort of calculation appeared. The very concept of thinking of the human being as a reasoning device, calculating according to some rules has its origin in Plato's ideas. Plato (428/427 BC–348/347 BC) argued that all knowledge has to be described in a form of pure explicit definitions. As a consequence, he believed that phenomena that could not be formalized explicitly, for example, bodily skills and feelings, could not count as knowledge. He therefore made a distinction between the rational mind and the body with its emotions and skills. He admitted that there is some kind of connection between the two of them, but he never explained how it worked. This was the starting point of the Western philosophical tradition, assuming that reckoning is the 'language of the mind' (Dreyfus [4, 5]). It was supposed that the matter of knowledge was embedded in the human mind from birth; the hard job was to bring forth this knowledge to consciousness, which is demonstrated in the Platonic dialogue between Socrates and the young slave boy *Meno* [6].

This conceptual separation of mind and body was confirmed by Aristotle (384 BC–322 BC) who divorced the practical from the theoretical and defined the human being as 'the rational animal'. Consequently, our sensorimotor skills and their relevance for coping with our surroundings were neglected and also the know-how in everyday activities [4, 5]. Aristotle made a distinction between form and its matter, and asked if the form can exist independently in the material world or 'in form of the mind' ("information" in today's terms, according to Freeman and Núñez [8]). In addition, Aristotle might be considered to have been the first biologist and ethologist, since he systematically studied animals and plants in his search for a "scheme of nature". He argued that the soul was the form of the matter of the biological body and argued that this was true in all living organisms. His classification attempts of animals resulted in a "ladder of life", which situated simple organisms at the bottom and the human being at the top. Aristotle's work can be regarded as a forerunner to evolutionary theory [9, 10]. The Greeks' view of knowledge continued to dominate in the Western intellectual tradition, and Aristotle reached his pinnacle during the middle Ages. However, in the eras of Renaissance and Enlightenment, philosophers also started to pay attention to findings made in the empirical sciences that had emerged [6].

The French philosopher René Descartes (1596–1650) also claimed that the mind is separated from the physical body, resulting in the concepts of two different substances, and formulated the *dualistic* viewpoint. According to Dreyfus [4, 5] and

Cisek [11], Descartes confirmed the ideas from Plato rather than adding anything radically new. Descartes was convinced that only humans possessed a rational mind, whereas animals and plants were mere machines, guided by their physical surroundings as puppets. Descartes' assertion is primarily disembodied in the sense that he viewed the mind as a non-physical substance, with almost no connection to the body, arguing that the human soul actually ruled the mind and directed the body how to behave. The only way to study this rational mind was to use Descartes' method of reason, which tried to ascertain how the mind (*res cogitans*) ruled the body (*res extensa*). Later philosophers, such as Hume and Kant, tried to analyze the function of the rational mind itself, and discussed what was possible or necessary to know about the world, and which possible constraints actually existed [4, 5]. According to Dreyfus [5], Descartes was the first person to imagine the possibility of building robots, but he also addressed some limitations in the machine itself, which he stated as follows:

> Although such machines could do many things as well as, or perhaps even better than men, they would infallibly fail in certain others For while reason is a universal instrument which can be used in all sorts of situations, the organs of a machine have to be arranged in a particular way for each particular action. From this it follows that it is morally impossible that there should be enough different devices in a machine to make it behave in all the occurrences of life as our reason make it behave (Descartes, 1637, quoted in [5], pp. 235–236).

Consequently, Descartes demonstrated or believed he demonstrated the need of a uniquely human soul as the 'pilot of the corporeal boat', since he was aware of the boundaries of this mechanistic view of non-human beings [4, 5, 8]. On the other hand, *vitalists* as Stahl (1660–1734), for instance, disagreed with the mechanistic view as proposed by Descartes. Instead, they argued that all living creatures were provided with some sort of 'vital energy' comparable to a spirit or soul. The debate between the proponents of these opinions was still ongoing when Darwin presented his theory of evolution (cf. [12, 13]).

2.2 Darwins Work and Its Legacy

Charles Darwin's book *The Origin of Species* [14] was a serious attempt to explain the development of the different species which inhabit our world. However, Darwin's theory was not the only one of its kind. Russell Wallace had developed a similar theory independently, which in fact forced Darwin to publish his own ideas [15]. Although not totally original, Darwin's theory was the first that actually could explain how change came about, which Darwin claimed was through the struggle for survival between individuals, the individual variations among conspecifics, and finally the proving that more off-spring are born in every generation than can actually survive to maturity. Darwin called it "natural selection" which Spencer later labeled "survival of the fittest". This line of argument was the cornerstone in the theory of evolution [10, 15, 16].

Darwin also assumed that patterns of behavior were the product of evolution, meaning that human behaviors had roots in animal behavior [17]. Although he was unwilling to talk about and discuss humans, he supposed that they are a part of the "tree of life", arguing that humans to some degree have a common past with other living beings [16]. Nevertheless, inspired by the improvement in 'hard sciences' like physics, Darwin tried to identify 'the laws of behavior' in both animals and humans. This way of thinking resulted in the book *The Descent of Man* [18], in which he argued that:

> [t]he difference in mind between man and higher animals, great as it is, certainly is one of degree and not kind. We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention, curiosity, imitation, reason, and so on, of which man boasts, may be found in incipient even sometimes in well-developed conditions in lower animals (quoted in [17], p. 3).

Darwin himself certainly believed there was a mental linkage between animals and humans, although this was a standpoint that many people, not least in Victorian England, had difficulties in accepting. Many agreed that the theory was adequate for animals, but not for humans who where considered unique due to 'their special minds' [9, 17]. However, as described by Sheets-Johnstone [19], Darwin strongly stressed the continuities of "mental powers", and did not separate the mental abilities from the actual body. Nevertheless, he argued as follows:

> [E]xperience shows the problem of the mind cannot be solved by attacking the citadel itself the mind is function of body we must bring some stable foundation to argue from (from Darwin's notebook 1836–1844, quoted in [19], p. 435).

It can be concluded that Darwin seriously stressed what today could be called an embodied approach to the study of the human mind. However, Sheets-Johnstone [19] argued that these lines in Darwin's work have been misinterpreted. Instead of studying the mind "as the function of the body", researchers have reduced the body and its interactions with the environment to include only the brain itself.

Furthermore, according to Ekman [20], Darwin was interested in ascertaining how our "habits had been gradually acquired". In particular he wanted to find an evolutionary explanation for human facial expressions and emotions. Darwin held the belief that expressions were "emblems for the emotions" and tried to describe which "emotional states" resulted in different expressions. He also investigated human facial expressions in different parts of the world in an attempt to discover whether they were universal or not [20]. As a result, in 1872 Darwin published *The Expression of the Emotions in Man and Animals* (hereafter referred to as Expression), which included not only human expressions and emotions, but also these from other animals, such as dogs, cats, horses, monkeys and apes. Darwin's way of explaining the expressive and emotional similarities between species was to ascribe animals (both high-level and low-level animals) with human-like emotions and feelings. For example, the dog feels *pleasure* when working because it is its duty, and the cat is in a *loving mind* when rubbing against somebody's legs, as well as ants are *despaired* when their ant-hill is destroyed [10, 21].

However, Darwin focused primarily on facial expressions and paid little attention to gesture and body language, which he considered the product of socially learned conventions, only mentioning their communicative role in a few words, and did not elaborate on them further. According to Ekman [20], Darwin's reason for ignoring these communicative features could have been an overreaction to Bell's claim that human expressions were God's gift to mankind. For that reason, he might have decided the best way of confronting Bell's opinion was to ignore it completely. Instead, Darwin [21] raised *what*, *how*, and *when* questions about emotions and expressions in general. Nevertheless, his main interest concerned *why* a certain expression is proper for a certain emotion. According to Ekman [20], Darwin was very interested in this 'why' issue and their significance to his idea of the continuity of species, since Darwin wanted to demonstrate that human beings were not a distinctive species, created by some kind of God. On the contrary, he insisted that also humans were the product of evolution. However, Bell had earlier successfully proposed that "there were muscles in the human face without analog in the animal kingdom, designed by the Creator for the display of specifically human emotions" [20]. Instead, Darwin's aim was to convince public opinion that the three principles of 'what', 'how' and 'why' could explain all primate expressions, which hopefully might result in an acceptance of his idea of the continuity of species. Creationists argued that if expressions were universal, it would be the result of the heritage from Adam. Instead, Darwin concluded that there were general significant similarities worldwide and claimed "the same state of mind is expressed throughout the world with remarkable uniformity" [21]. Accordingly, human emotional expressions and facial gestures are innate, since their universality is a result of evolution, and therefore not a uniquely human capability [20].

According to Cosmides et al. [15], Darwin was the first to actually combine psychology and biology, but he was also responsible for the split between the two. Darwin's work was in fact a serious attack against dualism, but the message was not recognized. This can be partly explained by his co-worker Wallace's personal view, which did not support the anti-dualistic stance. Wallace was actually devoted to the Cartesian worldview, arguing that human mental abilities have to be explained in supernatural terms, as a kind of soul [15]. Hence, Darwin, in fact, tried to bridge this gulf between body and soul in his work (cf. [18]), arguing that mental abilities could be explained in the same evolutionary way as the physiological factors. As a result of his fear of public opinion and lack of support from Wallace on this issue, Darwin elaborated two parallel lines of explanations for the development of the human mind. These were a *phylogenetic* explanation that stressed descent, and an *adaptationist* explanation that emphasized selection [15]. The adaptationist perspective has merely been factored out within psychology, and only the phylogenetic branch has been explored. This is in fact partly due to Darwin himself, since he mainly tried to explain the human mind from a phylogenetic perspective, making the case for the idea of a common human ancestor, originating from Africa [15]. That is, Darwin believed in a single universal line of development, with roots from lower animals to fulfillment in the supposedly 'highest' human being, i.e. the contemporary European. In order to validate this claim, he had to run counter to the argument presented earlier in *Descent*

[18], in which he had stressed the role of environmental conditions and adaptations, resulting in several lines of evolutionary development [22]. Consequently, Darwin had to argue that a kind of supremacy of reason to inherited endowment existed.

Nevertheless, Ingold [22] pointed out that Wallace indeed had found some deficiencies in this line of argument. He was in fact more familiar with indigenous people than Darwin, arguing that so-called 'savages' were really endowed with the same intellectual powers as Europeans, and that these 'primitive' people had also realized sophisticated cultural achievements. However, Wallace was unable to explain his view according to the theory of 'natural selection', and therefore devoted the endowment of superior brains to creationism [22]. In addition, the adaptationist perspective would not fully support Darwin's claim of a single line of development view, because this line focused on the *differences* between separate species. Hence, Darwin suspected that the adaptationist perspective of his theory really should have convinced the dualists they were actually right, namely that the human being is the unique species. Consequently, they may interpret that different qualities in separate species really could lead to such matters as a soul in humans [15].

Despite the disruptive issues addressed above, *Expression* can be said to have been the first serious work on behavior in history [15, 16]. According to Allen and Bekoff [23], Darwin usually attributed cognitive abilities to animals on the basis of his own observations instead of using controlled experimental studies and this approach resulted in an 'anecdotal cognitivism'. Despite this anecdotal approach, he seems to have been the first person in history to apply a comparative and phylogenetic method to the study of behavior [23]. Although his empirical methodology can be regarded as convenient in today's terms, Darwin's initial behavioral observations had a great impact, resulting in an increased interest in the study of behavior [15, 16]. Darwin's ambivalent view resulted in two contrary lines of behavioral research, the *anthropomorphical* line and the *mechanistic* line [12, 13]. The anthropomorphical line overstressed the mental abilities of animals, for example, beavers were described by Lewis Morgan as having an extraordinary understanding of hydraulics and architecture, a conclusion he made by observing the beavers' ability to build advanced constructions of nests, channels and dams. However, he had actually been deceived by the beavers' innate behavioral repertoires [10, 17, 24]. Moreover, the main proponent of this anecdotal line was Darwin's disciple Romanes, who presented anecdotes of 'clever' animals in his book *Animal Intelligence* in 1882, in which he inferred mental phenomena quite subjectively, e.g. fish were reported to experience jealousy and spiders as enjoying music [10]. However, Romanes' uncritical appraisal of animal mental abilities resulted in an attack by another Morgan in 1894, namely Lloyd Morgan, who became well known for his declaration, nowadays referred to as "Morgan's canon", which states [25]:

> In no case may we interpret an action as the outcome of the exercise of a higher psychological faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale (p. 53).

Lloyd Morgan was critical of anecdotal anthropomorphism, but did not claim that animals in fact lacked mental abilities, since 'lower psychological states' actually are mental states. Hence, Morgan insisted that scientists should rather try to find a simpler and more restrictive explanation of a behavior, instead of attributing higher mental capacities to animals [23, 24].

This line of argument should be considered in the case of the horse *Clever Hans*, which was one of the most famous examples of 'intelligent' animals in the early 1900s [10, 17, 23]. His owner believed that animals were as clever as humans, if they were given the opportunity to become educated. He therefore trained his horse Hans, which apparently turned out to possess remarkable cognitive capabilities. Consequently, 'Clever Hans' was regarded as a prodigy, since the horse was able to solve mathematical problems and answer questions, by tapping the correct answer with his front leg. Moreover, the horse was able to return the correct answers with or without the presence of his trainer. Although many scientists, for instance the prominent Oskar Heinroth, were skeptical of the horse's abilities, in their investigations of the case they were unable to discover any fraud or evidence that the horse was actually cued by its trainer. But in 1904 the mystery of 'Clever Hans' was revealed by Oskar Pfungst. He concluded that the horse did not really understand the questions, but instead was skilled in reading human body postures, e.g., a minor elevation of the eye-brows, holding the breath for a second or straightening one's posture. These visual hints cued 'Clever Hans', since the questioner unconsciously altered body and/or head posture(s) when the horse reached the correct number of hoof taps, as a kind of involuntary relaxation of the "pressure" of the situation. As a result, 'Clever Hans' could not present the right answer when the questioner himself did not know the correct answer, since the horse was then not able to notice the slight change in body posture when the right answer was at hand. The story of 'Clever Hans' was in fact the first scientific case demonstrating that it could be hazardous to appeal to consciousness or any cognitive abilities in explanations of animal behavior. The horse had actually learned to associate events, and the 'Clever Hans debacle' resulted in an ending of anecdotal cognitivism, following Morgan's canon [17, 23]. Although, the 'clever' horse failed to be good at arithmetic, he was in fact very sensitive to perceptual cues, and excelled in reading human bodily postures. According to Knapp and Hall [26], it has been demonstrated that horses are able to recognize changes in bodily postures as tiny as 0.2 mm, such as slightly dilated nostrils. Furthermore, the story of 'Clever Hans' might also serve as an illustrative example of the role of embodiment in social interaction, since this case highlights two important points. Firstly, humans continually show their feelings and attitudes, and secondly, that other beings both humans and animals are able to sense and interpret these aspects, although their interpretations might differ significantly.

Returning to the discussion of the two separated lines of behavioral research, Douglas Spalding argued that 'clever' behaviors were built into the animals mind from birth. He proposed that behavior in a sense was automatic in both animals and human beings, arguing that 'voluntary acts' were the result of automatic inborn nervous processes. Both humans and animals were "conscious automata", with no free-will or independence of the laws of nature [10]. Hence, this was the mechanistic line of research influenced by Darwin, given that he contrasted in his book *The Power of Movement in the Plants* [27] the downward digging behaviors of earthworms and moles with the tendency of plant roots to grow downwards, and then explaining both behaviors as a response to gravity. This concept was further developed by von Sachs, who demonstrated *tropism*. Tropism is the non-voluntary action driven by external forces, such as light or gravity in flowers' and plants' tendency to turn towards the sun [12, 28]. Ziemke [12, 13] pointed out that Loeb (1859–1924) was the most radical and influential of the mechanistic theorists, heavily inspired by von Sachs' work on tropism. Loeb identified similar behaviors in several simple organisms and extended the notion of tropism to include animal behavior. Hence, this led to the mechanistic assumption that *both* animals and humans were just objects directed by the environment, lacking subjective mental abilities. Loeb declared higher animals and humans were controlled by environmental forces, arguing that human beings were "biological machines", with a kind of robot-like quality in today's terms. However, Loeb pushed his idea to the extreme, and his explanations of both animal and human behavior were too simple and were strongly criticized by, for example, von Uexküll (see Sect. 2.4.1 and [10, 12, 13]).

Another proponent of mechanistic theories was Sherrington (1857–1952) who studied and identified *reflexes*. He illustrated in *The Integrative Action of the Nervous System* [29] how the nervous system integrated reflexes into adaptive behaviors and explained in what ways reflexes operated. Sherrington declared that the reflex was the fundamental unit of behavior, characterized by the *reflex arc*. He argued that this reflex arc was organized in three distinct structures; an effector organ which was stimulus sensitive, being wired via a nervous pathway to a receptor which initiated a response [24]. Thus, the behavior of the body was predetermined by the wiring of the nervous system that linked stimulus to response. Furthermore, Sherrington claimed that this notion of reflexes was an abstraction, arguing that no part of the nervous system could react without affecting the *whole* nervous system, since all parts were intertwined together (see [12, 13]). Hence, Sherrington's notion of the reflex arc would strongly influence the research of behavior, although it was biased and interpreted differently. Furthermore, Ziemke [12] noted that Loeb further developed von Sachs' work on tropism, extending the notion of tropism to include animal behavior. However, Loeb's theory of tropism fell short from empirical results, and he unfortunately confused the notions of tropism and taxes (nowadays the former concept refers to 'immobile' plants, whereas the latter concept refers to mobile organisms). Despite this mistake by Loeb, the importance of tropism and taxis has proved to be significant in the study of animal behavior. In 1940, Fraenkel and Gunn published the book *The Orientation of Animals: Kineses, Taxes and Compass Reactions* [30], which strongly agreed with Loeb's view of the objective study of animal behavior, and the book contains many examples of different sorts of taxis. Fraenkel and Gunn [30] argued that many kinds of animal behavior can be described by different taxes, either working together or against each other. As pointed out by Ziemke [12] as well as by Sharkey and Ziemke [31], contemporary work on behavior-based robotics and AI has its roots in the early work on taxes.

Cisek [11] identified two important issues in the research on behavior during the end of the 19th century and the beginning of the 20th century. Firstly, he pointed out the split in the study of living organisms. As a result, one line of thought concentrated on studying behavior as such, whereas the other focused merely on bodily physiology. However, Cisek argued that the motive for this split was for practical reasons, although it indirectly led to a gulf between the discoveries made within the field of behavioral studies on the one hand, and the field of physiology on the other, which resulted in a lack of communication between these two research fields. Secondly, Cisek argued that the behavioral sciences as a whole have been suffering because an 'envy' of the formal approaches, such as logic, mathematics, and physics. They have attempted to explain and verify behaviors and mental phenomena in a mathematical way, in order to validate their scientific endeavor, arguing that it would otherwise not be recognized as 'real' science [11]. As a consequence, these fields have tried to discover the 'laws of behavior', which Darwin attempted as well. Hence, the legacy of Darwin's work resulted in the split within the study of behavior and the unanswered question of dualism. One line of thought became experimental psychology which dealt with issues regarding learning and intelligence, and the other line became the scientific study of animal behavior and how they perceive the world (later known as ethology). As a result of these two branches, experimental psychology and ethology, scientists also developed different research methods [15, 16].

In the late 19th century, some researchers began to explicitly study human behavior, and in 1879 Wilhelm Wundt established the first psychological laboratory in Leipzig, Germany [32, 33]. In attempts to find the "atoms of the mind", Wundt tried to explain behavior by referring to the thoughts, feelings and emotions which crossed the mind during conscious experience, This method of working was termed *introspectionism* and had a tremendous impact during the early days of experimental psychology [6]. Wundt also provided the first classification of gestures that was intended for scientific purposes, but this line of research did not continue. Moreover, in the United States, William James conducted studies on mental capabilities from another perspective [32]. James was critical of introspectionism, and instead followed the adaptationist line of Darwin, paying particular attention to brain functions and instincts. He claimed that the mind consists of functionally specialized mechanisms or instincts, and each of them had evolved via adaptation to handle different issues. James sought to investigate these procedures of mental activity in daily life, and this standpoint became known as *functionalism* [6].

Indeed, the prevailing "units of analysis" in experimental psychology were actually *stimulus* and *response*. Psychologists had been influenced and inspired by discoveries within physiology in general, and the function of the nervous system in particular. However, the notion of the reflex arc became misinterpreted by psychologists. The initial description of the reflex arc implied a neural circuitry of 'coordinated action' [29], but the psychologists considered it as two distinct units [16]. They assumed that this process began with the stimulation of the organism, which initiated some sort of a mental act or awareness, resulting in a response. This means, they separated the stimulus from its response, and treated the response as a separable and independent event, which they claimed was the effect or result of a dependent stimulus. James [34], for example, stated that "[t]he whole organism, it will be remembered, is, physiologically considered, but a machine for converting stimuli into reaction" (p. 372). However, Dewey [35] was very critical of this restricted interpretation of the reflex arc, arguing that this psychological model actually was a legacy of mind-body dualism [2].

Hence, Dewey [35] proposed an alternative view, arguing that the organism interacts with the world through self-guided activity that coordinates and integrates sensory and motor responses. He addressed the need for a new description of the reflex arc, and he proposed the function of circular sensory-motor *coordination*, claiming "[w]hat we have is a circuit, not an arc or broken segment of a circle. This circuit is more truly termed organic than reflex, because the motor response determines the stimulus, just as truly as sensory stimulus determines movement" (p. 363). For this reason, Dewey rejected the linear model of stimulus and response, and argued that all activity is always an on-going 'sensory-motor coordination' [35]:

> Upon analysis, we find that we begin not with a sensory stimulus, but with a sensori-motor coordination, the optical-ocular, and that in a certain sense it is the movement which is primary, and the sensation which is secondary, the movement of body, head and eye muscles determining the quality of what is experienced. In other words, the real beginning is with the act of seeing; it is looking, and not a sensation of light. The sensory quale gives the value of the act, just as the movement furnishes its mechanism and control, but both sensation and movement lie inside, not outside the act. Now if this act, the seeing stimulates another act, the reaching, it is because both of these acts fall within a larger coordination; because seeing and grasping have been so often bound together to reinforce each other, to help each other out, that each may be considered practically a subordinate member of a bigger coordination (pp. 358–359).

Hence, the 'act of seeing' is related to the circumstances of the situation in which the looking process occurs. According to Dewey [35], meaning and response emerged together and there was no need for an analyzing or higher descriptive function, it is sufficient with a lower level motor-sensory coordination. Thus, this view proposed an alternative explanation of how the mind works, without an intervening "consciousness" controller as a kind of soul. In my opinion, Dewey actually stressed the situated and embodied nature of mind, first by stating the circumstances in a particular situation (situatedness), and then describing the underlying mechanisms in the form of its sensory-motor coordination (embodiment) in that particular situation. However, the aspects of introspectionism and functionalism (together with Dewey's view of sensory-motor coordination) should be swamped away and replaced by *behaviorism* [6]. Behaviorists argued that it was misleading to study either sensations or the operations of the mind or to consider bodily contributions. Skinner [36], for instance, argued that the arbitrary associative links between stimuli and response were merely the outcome of learning, and claimed that the way in which an animal or human was *embodied* was entirely irrelevant.

2.3 Behaviorism

Following and expanding Lloyd Morgan's argument, behaviorists argued that only observations of overt behavior should be the object of study. The initially false assumption about Clever Hans' cognitive ability resulted in an attempt to bring psychology more in line with the so-called ‘hard sciences’, focusing on replicable, controlled experimentation that recorded measurable behavior. The reason for this methodology was that these methods would make it possible to control and manipulate behavior and then provide explanations that covered the behavioral patterns of both animal and humans during variable conditions [23]. Behaviorists followed Darwin’s statement of a “mental continuum” between animal and man, then arguing that animals could be viewed as simple models of human learning. Thus, behaviorism was the first rigorous attack against the dualistic assumption, since it totally ignored any mental content. However, little, if any, interest was directed towards in what ways an organism was *embodied*. Hence, research on the role and relevance of bodily contributions to cognition was overwhelmed by the tide of behaviorism (cf. e.g. [3, 10, 15, 23, 37]).

Behaviorism has some of its roots in the work of animal learning from the beginning of the 20th century, such as the work of the Russian scholar Pavlov [16, 17]. Pavlov studied the mechanisms of digestion in dogs and regarded the biological body as a machine (following the mechanical view), arguing the digestive system functions like a factory. He measured the quantity of saliva produced during feeding in the dog’s mouth and discovered the *conditioned reflexes*, arguing they were the “atoms of action”. *Classical conditioning* was identified around 1905 when Pavlov noticed that the dogs started to salivate before the food was at hand. The dogs learned to associate the sound of the dishing out of food with its delivery. As a result, Pavlov constructed the formula that a sign stimulus resulted in a physiological response. Moreover, Pavlov noticed that if a bell or a similar sound was repeatedly activated just before the unconditioned stimulus was presented, this conditioning (or training) stimulus would finally trigger the salivation response itself, which was called *operant conditioning* or *learned conditioning*. Pavlov supposed that any cue an animal could sense could be used as a conditioned stimulus for every response [10, 16, 17].

Another person who also investigated animal learning was Thorndike (1874–1949). Although he studied chickens running through different mazes, there was a significant difference between his own and Pavlov’s experiments [10, 16]. While Pavlov’s dogs were always rewarded, Thorndikes chickens were only rewarded when they performed the desired behavior, which also led to improved results. Consequently, Thorndike proposed the existence of a “law of effect”, i.e. responses to a certain situation that was followed by ‘satisfaction’ or success were strengthened, and vice versa (‘discomfort’ or ‘failure’ resulted in weakness), and therefore there was no need for any mental content. However, Thorndike did not explicitly claim that humans actually behaved in the same way as animals [10, 16].

Hence, the mechanistic view proposed by Loeb and Sherrington was strongly in line with Pavlov’s work, which offered the behavioral sciences some physiological respectability. This happened during an era when the behavioral sciences were still envious of the formalistic or ‘hard’ sciences, and there was a need for an ‘objective’ science of behavior, especially after the embarrassing ‘Clever Hans debacle’ [16]. As a result, behaviorism, which became the dominant approach from the beginning to the middle of the 20th century in the United States, emerged [10, 16, 17]. In 1913 Watson published *Psychology as the Behaviorist Views It* [38], in which he argued that psychology should only study carefully defined stimuli and their overt responses, and then formulated rules that predicted which behavior should be the result of a given stimulus [17]. Moreover, scientists had to neglect every speculation about what might be happening in the 'mind'. Watson and Loeb met, and agreed that animals were "mindless machines" [10]. However, Watson [39] went beyond Pavlov's assumptions of the power of classical conditioning and instead argued that *all* behavior is learned, even the physiological bodily processes, arguing:

> [T]here are then for us no instincts- we no longer need the term in psychology. Everything we have been in the habit of calling an 'instinct' today is largely the result of training … [Think] of each unlearned act as becoming conditioned shortly after birth - even our respiration and circulation (Watson, quoted in [17], p. 48).

Hence, behaviorists claimed, contrary to the views of Darwin and James, that instincts actually do not exist. Instead, all behavior is the result of learning and "all mental content comes from the external world", via association processes that link stimulus and response [15]. Moreover, Watson [39] argued that all learned responses were chains of unconditioned responses in a form of 'reflex chains' and this learning process was supposed to be *equipotential*, meaning there was no inherent advantage of some stimulus-response association over another possible stimuli-response association in the organisms [15]. In addition, the proponents of behaviorism reinterpreted Darwin's work, but they over-stressed his idea of the mental continuum of species, which resulted in some misleading conclusions. Watson and his colleagues argued that humans and animals in fact learn and behave similarly, and as a result, scientists would gain knowledge of human behavior by studying rats, pigeons and other animals, as well as experimentally controlling their environments in a way that was not ethically acceptable for humans [15]. Ironically, behaviorism, which had its roots in Darwin's claim of phylogenetic continuity, resulted in an intensely anti-Darwinist view as behaviorists argued that Darwin's theory of evolution would not shed any light on human behavior. On the other hand, they claimed that learning and environmental factors in one way or another "insulate behavior from evolutionary shaping and analysis" (Skinner cited in [15]).

Skinner was more radical than Watson, arguing that scientists should treat the mind as a "black box" [40]. He asserted that no statements or investigations of the mind should be made, since there was no mental content, no instincts, no abilities and no emotional processes. The mission of the behaviorists was to explain human behavior in terms of classical and operant conditioning, stressed by the mental continuity of the species. The only inherited ability in animals and humans was the "genetic endowment" of classical and operant conditioning [15]. Consequently, *antimentalism* and *equipotentiality* were the two pillars of behaviorism. However, these behavioristic assumptions were too optimistic and exaggerated, and several scientists criticized this behavioristic manifesto already during its heyday. As discussed in the following section, the main reasons for their criticism were either they had discovered phenomena which could not be explained in behavioristic terms or they actually paid attention to mental content.

2.4 Beyond the Bounds of Behaviorism

There were researchers, mainly outside the United States, who were not devoted to behaviorism, and conducted work in other directions. This section presents some of these works, focusing on approaches and theories that can be viewed as early attempts of embodied and/or situated theories of cognition, as well as the social nature of cognition, although not explicitly expressed under these labels. The work of von Uexküll and the succeeding branch of ethology, the work of the Gestalt school and the philosopher Merleau-Ponty, Piaget's genetical epistemology, and the socio-historical approach proposed by Vygotsky are briefly outlined. Furthermore, Bartlett's work on social cognition is included, and then we meet Dewey again, since his philosophical epistemology has strong similarities with the theories of embodiment and situatedness. Finally, Mead's work on the relational nature of intelligence is portrayed.

2.4.1 The Field of Ethology and the Work of von Uexküll

As a consequence of the major impact of behaviorism in the United States, *ethology* emerged primarily as a research field in Europe. According to Alcock [41], it might be argued that the academic field of animal behavior actually emerged in 1937, when the first journal within the area appeared (in German), but it was in fact during the 1950s that the research field as such became widely accepted as a serious branch of science. Burghardt [42] for instance, declared that the "naturalistic study of animals, focusing on activities essential to their survival and informed by an evolutionary attitude, is the hallmark of ethology" (p. xvii). Hence, the underlying approach in ethology is biological rather than psychological, and its founders stressed the importance of studying animals in their *natural* habitats and not in artificial environments such as laboratories and Skinner boxes. While the proponents of behaviorism almost denied any forms of instincts, arguing for their equipotential assumption, ethologists instead followed Darwin's adaptational line and stressed the importance of innate behaviors [16]. As described by McFarland [16], Darwin's impact on ethology was strong and threefold. Firstly, the theory of natural selection laid the foundation for studying animal behavior from an evolutionary point of view. Secondly, his ideas on instincts can be considered a precursor to the inception of classical ethology. Finally, his work resulted in an increased interest in studying animal behavior as such.

The roots of ethology can generally be found in the early work of European zoologists, but the fundamental discoveries that founded the branch of ethology were in particular Whitman's and Heinroth's taxonomy of, and comparative work on, different behavioral patterns in birds [43]. Although Heinroth formulated the "comparative study of gesture" and named it *ethology*, it was actually his disciple Lorenz, who became the main promoter of the new science (besides Lorenz, the founding fathers of ethology are today usually considered to be Tinbergen and von

Frisch [6, 10, 41, 44]). Lorenz, for instance, particularly emphasized the importance of sensitive observations of wild and 'domesticated' wild animals that he had raised in his home. Tinbergen and von Fritsch conducted simple, though very significant experiments, in the natural field as well as on captive animals in 'natural' conditions [45, 46].

Another influential person was Jakob von Uexküll (1864–1944) who had a tremendous impact on ethology in general, and Lorenz's work in particular [12, 13, 44]. According to Walther [44], although von Uexküll's ideas strongly influenced Lorenz, he rarely credited von Uexküll's work. This neglect was probably due to von Uexküll open and profoundly anti-Darwinian standpoint, which was contrary to the opinion of Lorenz, who was personally a great admirer of Darwin's evolutionary theory. Probably also as a result of his anti-Darwinian stance, von Uexküll's work became less known during his lifetime, though he was not against evolutionary explanations as such.[1]

Another reason might be the fact that he published only in German [12, 13, 44]. Von Uexküll coined the term *Umwelt* in order to describe the surrounding and unique subjective world of each species, including humans. That particular concept has recently received much attention in embodied cognitive science and robotics (cf. e.g. [12, 13, 48–50]), and von Uexküll's work is probably the most influential from the field of ethology in contemporary discussions of embodied cognition.

Von Uexküll was initially active in physiology but has become better known for his later work in theoretical biology. According to Ziemke [12, 13], von Uexküll was strongly inspired by Kant's notion that all knowledge is determined by the knower's subjective perception and consideration, arguing that biologists have to study "*the phenomenal world or the self-world of the animal*" ([47], p. 319). Indeed, von Uexküll argued that the task of biology was to improve Kant's work further, by more fully examining the role of the body, and the relation between subject and object. He strongly criticized the mechanistical theories in general, and the work of Loeb in particular, although he did acknowledge the role of chemical and physical 'forces' in the behavior of quite simple organisms [51]. Accordingly, Uexküll [51] investigated which factors in its surroundings might affect the organism, and how this occurred.

In order to answer these questions, he began with the organism itself, as opposed to an anthropocentric view, according to which the human world-view is completely separated from other species. As a result, nearly all human objects and artifacts might disappear and only the objects remains that exert an effect on the organism in correlation to its construction plan, and "*the construction plan by itself creates the environment of the animal*" ([51], p. 223 original emphasis). Hence, von Uexküll [51] differentiated between objective (Umwelt) and subjective (Innenwelt) experiences, arguing that it is essential to understand both in order to fully comprehend an organism's behavior [23]. The 'inner world' of an organism is made up by the construction plan, which filters out and regulates the crucial factors of the surroundings. Von Uexküll strongly argued that the basis for biology would be to study the

[1] von Uexküll seems to have believed that God was the force behind the 'divine' plan [47].

construction plans of different species, bringing the fields of anatomy and physiology together again [51]. This means, the research focus of biology, in von Uexküll's view, should be the study of how the environment and the inner world are connected to each other. However, his own empirical work was limited to studies of invertebrates, whereas his theoretical work addressed both 'lower' and 'higher' animals [51]. Broadly speaking, he proposed that a 'special biology' of all animal species could be realizing through studying the organization of the building plans in separate species and then comparing them. Hence, these comparative analyses should not only focus on the actual functions, but also concentrate on different materials or tissues, thus criticizing Loeb's work on tropism for only addressing the former aspect.

Consequently, he was critical of behaviorism as well, arguing that their proponents ignored the organism's subjective and embodied nature of being by treating [47] "all living beings as mere machines" from an objective standpoint (p. 319). He maintained that the proponents of these theories had disregarded the importance of subjective experiences, paying no attention to the subject's (embodied) experience, for instance, how our sense and motor organs supply our perception and actions. In his own words [47]:

> The mechanists have pieced together the sensory and motor organs of animals, like so many parts of a machine, ignoring their real functions of perceiving and acting, and have even gone to mechanize man himself. According to behaviorists, man's own sensations and will are mere appearance, to be considered, if at all, only as disturbing static. But we who hold that our sense organs serve our perceptions, and our motor organ our actions, see in animals as well not only the mechanical structure, but also the operator, who is built into their organs, as we are into our bodies. We no longer regard animals as mere machines, but as subjects whose essential activity consists of perceiving and acting. We thus unlock the gates that lead to other realms, for all that a subject perceives becomes his *perceptual world*, and all that he does, his *effector world*. Perceptual and effector world together forms a close unit, the *Umwelt* (p. 320).

This means that different species experience the surrounding world in different ways due to their various body designs perception capabilities. It has been noticed that a bee perceives its surrounding world quite differently from a human, since they, for example, can see infrared light, which humans cannot do by nature (without an apparatus). Therefore, the bee's subjective view of the world is separate from the human perception and interpretation of the 'same' world, since they inhabit their own 'effective environments' (cf. [49]).

In order to illustrate his idea of *Umwelt*, von Uexküll [47] used the tick as an example, illustrating the gulf between the subjective experiences of different species. In fact, the mated female tick needs a blood meal before she can lay her eggs, and in order to complete that task, it has to be equipped with certain sensory and behavior repertoires so called functional circles. It is through several such *functional circles* that the tick becomes embedded in its own world. The tick is guided through those circles via particular *perceptual* and *effector signs*. The tick's skin is sensitive to light, thus leading it up from the ground to a brighter position on a branch or grass blade. There it hangs until a mammal passes by which emanates butyric acid, and once that butyric acid reaches the ticks receptors, it drops onto the mammal. This means, the *perceptual sign* of butyric acid alters into a perceptual cue that in turn triggers an *effector sign*, releasing the tick's legs which allows and the tick to drop onto the mammal. When the tactile cue of hitting the mammal's coat is triggered, the tick begins to move around, searching for *warmth*, and when it finds the skin it will trigger a burrowing behavior, after which the tick starts to burrow in and suck blood. However, the tick has no sense of taste, and will drink any fluid of the right temperature once it has perforated the membrane. When the tick has finished her first and last meal, it will drop down, lay her eggs in the earth, and then die.

However, the mammal continues to generate butyric acid during the later stages, although the acid has lost its meaning for the tick, since it is actually sensitive to certain signs at different phases. Hence, the relation between the object and the subject is illustrated as a *functional circle*, which is not a set of random reflexes, but rather a collection of context dependent [47] "well planned successions" (p. 324) which follow after each other. According to Ziemke [12], von Uexküll should neither be considered vitalistic nor mechanistic. Instead, he stressed that the organism's parts are created in such a way that they together will form a *whole*, a kind of behavioral entity, functioning as an acting subject. Consequently, that behavioral entity emerges into a "systematic whole" through its functional embedding in its Umwelt, which he stated as follows [47]:

> We are not concerned with the chemical stimulus of buturic acid, any more than with the mechanical stimulus (released by the hairs), or the temperature stimulus of the skin. We are concerned solely with the fact that, out of the hundreds of stimuli radiating from the qualities of the mammal's body, only three become the bearers of receptor cues for the tick. Why just these three and no others?
>
> What we are dealing with is not an exchange of forces between two objects, but the relations between a living subject and its object. These occur on an altogether different plane, namely between the receptor sign of the subject and the stimulus of the object her *Umwelt* (p. 325).

As described by Ziemke [12, 13], von Uexküll [52] distinguished between living organisms and machines, and the major differences lie in the *construction* and the *autonomy* of the system itself, and the former is described as follows:

> Every machine, a pocket watch for example is always constructed centripetally. In other words, the individual parts of the watch, such as its hands, springs, wheels, and cogs, must always be produced first, so that they may be added to a common centerpiece.
>
> In contrast, the construction of an animal, for example, a triton, always starts centrifugally, from a single cell, which first develops into a gastrula, and then into more and more organ buds.
>
> In both cases, the transformation underlies a plan: the 'watch-plan' proceeds centripetally and the 'triton-plan' centrifugally. Two completely opposite principles govern the joining of the parts of the two objects (von Uexküll 1928, quoted from Ziemke [12], p. 17).

This means, von Uexküll [52] particularly stressed that living organisms have an innate "meaning-quality" in their organs, contrary to the parts of a machine which can never develop centripetally, a line of argument closely related to his notion of the *autonomy* of living systems versus machines. As described by Ziemke [12], von Uexküll [52] argued that "each living tissue differs from all machines in that it possesses a ‘specific’ life-energy in addition to physical energy” (p. 34). However, this ‘life-energy’ is a kind of quality in the chemical/physical system, and not some ‘vitalistic’ immaterial energy. This ‘life-energy’ makes it possible for cells to respond to certain stimuli in a particular way, since living cells are able to perceive and act according to their specific receptor and effector signs. As a result, the behavior of the organism is “meaningfully organized” and not “mechanically regulated” according to von Uexküll [52]. He argued that machines operate mechanically, simply following the physical and chemical laws of cause and effect and not able to either grow or change. He furthermore claimed that machines have fixed structures, created and ‘built in’ to the machine by the human designer. Hence, machines are *heteronomous*, since they cannot regenerate or repair themselves if they break down [12, 13]. Living organisms, on the contrary, can both grow and regenerate on their own, since they have their functional role themselves, allowing the tissue to repair and grow autonomously. In sum, von Uexküll claimed that “*machines act according to plans* (the human designers’), whereas *living organisms are acting plans*” ([52], quoted from Ziemke [12, 13]).

According to Burghardt [42], von Uexküll’s work provided the inspiration for several classical ethological concepts such as *sign stimulus*, *releasers*, and *innate release mechanisms*. During this initial era of ethology the belief was that animals at times responded in an instinctive manner to specific stimuli so-called *sign stimuli*. Alcock [41], for example, defined an instinct “as behavior that appears in fully functional form the first time it is performed, typically such behaviors are mechanically triggered by a simple cue of some sort” (p. 25). For instance, Tinbergen [53] conducted some experiments with male sticklebacks that are sensitive to red spots, and his results suggested that it might be some *innate release mechanisms* (IRM) in the fish. In addition, Lorenz [43] argued that much of animal behavior was constructed by some “fixed-action patterns” or species dependent instincts, and mainly genetically determined [41].

Alcock [41] pointed out that early ethologists studied many behavioral cases, which were not easily altered by specific environmental influences. Tinbergen and Perdeck [54], for instance, discovered that newly hatched herring gulls somehow ‘know’ how to be fed. They pecked at a red dot on the bills of their parents, which responded by regurgitating some food. Another example, also described by Alcock, concerns the rolling behavior in the incubating greylag goose. If an egg was taken and placed at a distance, the goose retrieved the egg to the nest using a standardized behavior pattern to roll the egg back [41]. Hence, from an observer’s point of view, it actually seemed as if the goose knew what to do. However, this behavior does not end even when the egg is taken away, since the goose will actually complete the behavior as such, with or without the egg (cf. [53]). Moreover, Tinbergen [55] discovered that gull chicks would rather peck at a long thin striped red stick than on a realistic model of a parent gull, since the red striped stick in fact functions as a ‘better’ releaser of begging behavior when the chick is quite young. Lorenz and Tinbergen called this instinctive response *fixed-action pattern* (FAP), and supposed that the fixed action pattern was the response which plays itself out to completion, once activated by a simple sensory cue. They called this key component of the object that triggers the

FAP a *sign stimulus* or a *releaser*, in the case when the sign stimulus was a social response between individuals [41]. This means, the red dot on the stick functions as a releaser for the begging behavior of the gull's offspring.

In sum, the field of ethology offered a comparative framework for the study of behavioral functions, evolution (phylogeny), physiology and behavior development (ontogeny) in animals (cf. [53]). These different levels of analysis are sometimes presented as *Tinbergen's four questions* (e.g. [56]), and provides a stable basis for the study of behavior [24]. This framework has also been applied on human behavior, in particular Eibl-Eibesfeldt's [57] work of *human ethology*. However, his work focuses on finding the 'pure nature' of human beings, although it can be questioned if the hunting and gathering people he studied actually represent the 'plain and true' nature of human beings, since these tribes are also embedded in a social and cultural surrounding. Thus, it can be argued that, in fact, there are no such 'natural' human beings (see the arguments against the view of 'natural' human beings put forward by Rogoff [58]).

2.4.2 From the Gestalt School to Gibson and Merleau–Ponty

Although the predecessor of the Gestalt school was Ehrenfels' work in the 1890s, on melody perception, the real starting point was Wertheimer's book concerning the visual perception of movement in 1912 and later studies conducted together with his assistants Köhler and Koffka [6]. They noticed that in human perception, the overall characteristics of an object, as its main shape or contour, were of greater importance than the partial elements [1]. As a result, proponents of the Gestalt school took a holistic approach, and argued that a solution to a problem may occur in one step, and not in several series of stimuli and responses as argued by behaviorists. The answer to a problem resulted in a form of a *gestalt*, explained as a 'picture in the mind', an 'insight' or a kind of 'aha-experience'. Consequently, Gestaltists concluded that "the whole is more than the sum of its parts". Besides the studies conducted on humans, Köhler [59] investigated the problem-solving abilities of chimpanzees, and concluded that this insight-ability or 'gestalt' was present in some great apes as well.

However, the Gestalt approach lacked a theoretical foundation for the perceptual phenomena observed, and as a result the research field failed to maintain its influential and central position. The reason for this is twofold. Firstly, new findings in neuroscience and initial models of information-processing provided seemingly plausible alternative explanations of the same evidence.[2] Secondly, advocates of the Gestalt school relocated to other places around the world, due to the political climate in Europe during the 1930s [1, 6]. However, some of the ideas of the Gestalt school were used as a foundation for the work of Gibson, who developed an *ecological*

[2]According to Dreyfus [4, 5] the Gestaltists would never have accepted the *computer metaphor for mind*, since they did not believe in stepwise instructions, they rather viewed the mind as an emerging whole; a kind of '*Gestalt*'.

approach of perception, in which he introduced the concept of *direct perception* in an attempt to bring the environment back into psychology, stressing the dependency of the context for our perceptual ability [60, 61]. He claimed that objects in the world *afforded* certain actions, allowing organisms to pick up certain 'invariants' and dynamical features of the environment. The organisms could then immediately transform this environmental information into action, without the need for any stepwise processes [62]. Hence, Gibson's general ideas can be viewed as situated/embodied in the sense that he emphasized the importance of the interaction between the agent and the environment for intelligent behavior.

The French philosopher Merleau–Ponty (1908–1961) was inspired by the Gestalt school and tried to find support for some of their ideas in his work. He claimed that the mind was essentially *embodied* and *interacting* with the surrounding world [4, 5]. Merleau–Ponty then further claimed that it is actually the body which provides meaning for the mind, thus taking a stance separate from both mentalism and materialism [63]. According to Priest [63], Merleau–Ponty was critical of behaviorism, arguing in *The Structure of Behaviour*[3] [64] that neither is psychology 'reducible' to biology nor is biology 'reducible' to physics. Instead, Merleau–Ponty suggested the human mind really functions in a similar way as the Gestaltists explained perceptual phenomena. This means, the interpreted perception of an object (or a person's behavior) in itself is ambiguous and dependent on the perceiver's (or observer's) own conscious or unconscious preconceptions, resulting in the emergence of different, alternative 'gestalts' or interpretations [63]. Hence, studying behavior from an observer's point of view, by 'objectively' noticing the physiology of the actions was insufficient, since no component of behavior could be reduced to its assumed sub-parts. Consequently, the whole behavior as such is always interpretable from different angles, since we can never eliminate alternative explanations of a particular action, and behavior is not the result of external causes alone [63]. Similarly, Merleau–Ponty [64] claimed that on the other hand, behavior could not be explained internally in terms of conscious intentionality [65]. Loren and Dietrich [65] pointed out that Merleau–Ponty was frustrated with the dualistic view in philosophy, and the "step back" or *epoché*[4] from the real lived world, which was the common view in phenomenology, as proposed by Husserl and Heidegger for instance. Merleau–Ponty maintained that these beliefs essentially divorced embodiment from consciousness and cognition.[5]

[3]Initially published in French in 1942, but the English version was published in 1963. The French original of the title word 'Structure' was the French translation of the German 'Gestalt' [63].

[4]According to Dreyfus [4, 5] this "step back" or *epoché* is the divorced study of consciousness from a kind of meta-level perspective, by putting the everyday experience and the outer world in brackets. It has its roots in Descartes' method of reason.

[5]According to Loren and Dietrich [65] as well as Priest [63], Merleau–Ponty did not separate cognition from consciousness. The analysis of cognition actually is one aspect in the analysis of consciousness. Hence, what counts as cognition counts as consciousness as well.

Merleau–Ponty was actually inspired by Heidegger's work[6] and the idea of 'being-in-the-world', but he went an essential step further, arguing that being embodied is the core 'essence' of human subjectivity of being in the world, which he stated as follows in his *Phenomenology of Perception*[7] [67]:

> [w]hen I reflect on the essence of subjectivity, I find it bound up with that of the body and that of the world, this is *because my existence as subjectivity is merely one with my existence as a body and with the existence of the world, and because the subject I am, when taken concretely, is inseparable from this body and world* (Merleau–Ponty, 1962, quoted in Mingers [68], p. 111, emphasis added).

Hence, Merleau–Ponty's core concept was the idea that 'I am my body' as a kind of "embodied cogito", i.e. it is not the brain that does the thinking, instead it is done by the body [65]. According to Merleau–Ponty's [67] ideas, the brain is merely a part of a larger system, the central nervous system and the whole body, and in order to understand intelligent behavior we must study the whole system. He therefore claimed that human behavior must be seen *structurally*, through the interplay between the body and the nervous system in relation to the environment. In order to do so, he pinned down Heidegger's more abstract level of description, and addressed both biological and physiological matters in his work, discussing different aspects of animal and human behavior [65, 68]. Hence, in his view, the behavior of an organism is the result of the interaction between the organism's subjective perception of the environment conducted by its body and nervous system, which he characterized as follows:

> The properties of the object and the intentions of the subject are not only intermingled; they constitute a new whole. When the eye and the ear follow an animal in flight, it is impossible to say "which started first" in the exchange of stimuli and responses. Since all the movements of an organism are always conditioned by external forces, one can, if one wishes, readily treat behaviour as an effect of the milieu. But, in the same way, since all the stimulations that the organism receives have in turn been possible only by its preceding movements which have culminated in exposing the receptor organ to the external influences, one could also say that behaviour is the first cause of all the stimulation But in the organism itself which chooses the stimuli in the physical world to which it will be sensitive. The environment (Umwelt) emerges from the world through the actualization or the being of the organism an organism can exist only if it succeeds in finding in the world an adequate environment (Merleau–Ponty, 1963 quoted in Mingers [68], p. 13).

Hence, this structural relation can be viewed as a kind of "circular loop", with no start- or end-points. This means, the world neither determines our perception, nor does our perception generate the world (cf. [69]). As a result, Merleau–Ponty disregarded dualities such as perceptive and motoric abilities, as well as object and subject. Instead, he argued that perception and action are entirely intertwined, because perception constantly entails motor (muscular) actions, and these actions in turn generate novel perceptions and so on. Consequently, there is no dominance of one side

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[6] A recommended introduction to Heidegger's work is Dreyfus' [66] *Being-in-the-world: a commentary on Heidegger's Being and time.*

[7] Initially published in French 1945.

over the other; instead there are "mutual affordances" between the organism and its external world [68]. Moreover, Merleau–Ponty claimed it is actually the body which has the necessary 'knowledge' to perform the task at hand, since the body 'knows how to act' and 'how to perceive' through the history of its phylogenetic and ontogenetic interactions with the environment. He [67] maintained that "[a] movement is learned when the body has understood it, that is, when it has incorporated it into its 'world"' (p. 139).

Loren and Dietrich [65] argued that Merleau–Ponty viewed this relation between the embodied organism and certain objects in the environment as *intentional*, i.e. the way an object appears to the organism is meaningful, although this does not necessarily mean cognitively meaningful, but rather that it is biologically meaningful. They further pointed out that Merleau–Ponty supposed this 'meaning' was the outcome of the body as such, claiming that bodies actually *are* conscious, which means bodies are 'cognitive' in themselves. Hence, he viewed cognition as a sort of biological phenomenon instead of a mental one, in view of the fact that our cognition is bound to the world through our embodiment, arguing that all organisms are "condemned to meaning" prior to any cognitive states. This bodily 'meaning' or 'intentionality' is the result of the organism's orientations to the world, depending on and affected by its past history, which he stated as follows:

> The gestures of behaviour, the intentions which it traces in the space around the animal, are not directed to the true world or pure being, but to the being-for-the-animal, that is, to a certain milieu characteristic of the species: they do not allow the showing through of a consciousness, that is a being whose whole essence is to know, but rather a certain manner of treating the world, of 'being-in-the-world' or of 'existing' (Merleau–Ponty, 1963, quoted in [65], p. 353).

The relation between the external world and the organism is represented in the states of the animal's nervous system, and these states mediate the animal's behavior in the environment. Additionally, bodily intentionality offers the necessary basis for cognitive intentionality, since it has its roots and origin in bodily intentionality. This means, Merleau–Ponty did not separate intentionality from the body as is usually done in more analytic formulations of intentionality [65].

According to Dreyfus and Dreyfus [70], as well as Dreyfus [71], Merleau–Ponty developed two significant concepts that actually address these 'bodily intentions', namely the *intentional arc* and the *maximal grip*. The 'intentional arc' is characterized by the close connection between the embodied organism and its world. It functions like a feed-back loop between the skills learnt from past experiences and the demands of the present situation at hand. The notion behind the intentional arc is that all past experiences are projected back on the world. The organism acts from its own point of view, and the outcome is due to the organism's history of past experience with similar situations or things. Hence, the organism is 'afforded' a certain response, which is guided by the organism's previous 'knowledge' or experience. Consequently, there is no need for representations in the mind, since the best representation of the outside world is the world itself, which is presented in this feed-back loop or intentional arc itself [71]. The 'maximal grip' then, is the body's tendency to respond to these demands in the most appropriate way, namely to bring forth a more optimal 'gestalt', from the organism's point of view. This is illustrated in the following statement:

> For each object, as for each picture in a gallery, there is an optimum distance from which it requires to be seen, a direction viewed from which it vouchsafes most of itself: at a shorter or greater distance we have merely a perception blurred through excess or deficiency. We therefore tend towards the maximum of visibility, and seek a better focus as with a microscope (Merleau–Ponty, 1962, quoted in [71], p. 378).

Furthermore, Merleau–Ponty [67] argued that all higher animals including humans always strive to get a maximal grip on a situation. However, this is not a goal-directed activity, instead it is purposive in the sense of being a kind of 'basic' motivation, since organisms always try to find a more optimal 'gestalt'. Hence, this basic motivation is the driving force, not any stated request to achieve a certain goal. The body is tuned by the situation to reach a flow of balance and equilibrium [70]. Hence, according to Dreyfus [71], the intentional arc is the result of the tendency toward a maximal grip.

According to Mingers [68], Merleau–Ponty tried to find in his last, but unfinished book *The Visible and the Invisible*[8] [72], the fundamental primitive of the mutual independence between the organism and its world, being eager to bridge the gap between object and subject. In order to do so, he went beneath his earlier notion of the *structural* relation between the organism and its world. Hence, he concluded that both sides rather are different aspects of the same primary whole 'brute being', namely the *flesh*. This new notion can be viewed as two sides of the same coin. This means, the lived body has a twofold character, being able to see or touch on the one hand, and being seen or touched on the other hand. Mingers [68] exemplified this by saying "when we touch an object we are also touched by it and, even more reflexively, when we touch ourselves we are both toucher and touched in a dual sense. It is like a measuring instrument that measures its own internal states" (p. 116). Hence, this double nature has its roots in the flesh, and in order to describe the very nature of the flesh, Merleau–Ponty argued the flesh is "not matter, is not mind, is not substance. To designate it, we should need the old term "element", in the sense it was used to speak of water, air, earth, and fire, that is: in the sense of a *general thing*, midway between the spatio-temporal individual and the idea" (Merleau–Ponty, 1969, quoted in [68], p. 116).

Thus, so far only questions concerning low-level perception and bodily intentions in Merleau-Ponty's work are addressed, but he actually tried, contrary to other phenomenologists, to situate his theory in a more cultural context [73]. The main reason for this cultural inclusion may have been his alliance with the French anthropologist Claude Levi–Strauss [63]. As a consequence, he argued that each aspect of being in the world was important, and therefore 'being-in-the-cultural-matrix-of-the-world' was an "indispensable moment of the lived dialectic" [73].

Merleau-Ponty [67] pointed out that these more 'basic' bodily intentions could be elaborated further by moving from a "literal meaning to a figurative meaning", maintaining that their new meaning obviously had a new significance. In order to explain this shift of meaning, he mentioned the skill acquisition of dancing and driving a car,

[8] Originally published in French 1964.

since both behaviors have roots in motor activities. This means, the embodied organism has to practice its muscular movements and bodily actions until it has developed the accurate patterns of behaving in a certain situation, and the very process is the same for cultural practices [4, 5]. In a similar way, he illustrated how abstract concepts derive their meaning from embodied experience. The notion of a triangle can be stated in an abstract mathematical way, but its underlying understanding can only be grasped through our embodied nature of being in the world ([68] but see the work of Lakoff and Núñez [74] mentioned in the Introduction chapter).

With respect to language, Merleau–Ponty [72] argued that human language rests on the same intentionality as its bodily counterpart, which has its roots in intentional relations such as desires, wants, and so on. He claimed that these intentions actually existed in the child before it had the ability to express them linguistically [65]. Moreover, he argued that the most basic form of communication is bodily behavior and these acts are the basic foundation for cooperation among organisms. Human language then, is an extension of these bodily acts. Children acquire language in the same way as they acquire other bodily or cultural skills, and the meanings of the words come through their practical use, since "[I] learn it as I learn to use a tool, by seeing it used in the context of a certain situation" (Merleau–Ponty, 1962, quoted in [68], p. 115). However, when humans actually have acquired a language, it will control human cognition and communication [65]. Merleau–Ponty treated the relation between language and thought as an intertwined process, arguing that the use of language actually is the process of thinking; either we speak to ourselves or to other persons. Hence, it is through verbalization that consciousness arises [68].

In sum, the main characteristics of Merleau-Ponty's work were his non-dualistic and anti-behavioristic explanation of embodied experience. He convincingly argued that bodies are intentional in themselves, as they know 'how to act', making cognition a biological phenomena rather than a mental one. Hence, he stressed the connection between action and perception, claiming that perception is really a motor act. Although he emphasized cultural aspects of embodiment, he stressed psychological explanations of perceptual phenomena more, probably as a legacy from his interest in the Gestalt school.

2.4.3 The Genetic Epistemology of Piaget

The Swiss scholar Jean Piaget (1896–1980) stressed the importance of sensorimotor activity for the emergence of intelligent behavior (e.g. Piaget [75, 76]), and he is well known for his cognitive development theory. In order to explain the process of intellectual development he proposed a *genetic epistemology*, meaning the study of the development (*genesis*) of different kinds o knowledge (*epistemology*). He did not primarily view his research as limited to psychology, but rather as a combination of biology and logic (cf. e.g. [77, 78]). According to Sinha and Jensen [79], the basic motivation of his genetic epistemology was to offer a developmental and biologically based reformulation of the philosopher Kant's synthetic theory of knowledge. Piaget, like von Uexküll, was deeply inspired by Kant's idea that the subject's knowledge is dependent on its own perceptual and conceptual abilities (cf. [13]). Although, Kant did not address the development process behind the forms and categories that are central in subjective experience, this developmental aspect became the major theme in Piaget's work [77]. During his life he was a prolific producer of literature, and this section can only very briefly address the central tenets of his work.

Cosmides et al. [15] pointed out that Piaget searched for a middle way between Lamarck's and Darwin's work, on the one hand, and the Gestalt school and behaviorism on the other, in order to realize his scientific endeavor (cf. [77]). Initially, Piaget was a biologist, studying how simple organisms (molluscs) adapted to their environment, arguing that organisms adapt to their environment by different processes. These processes are 'innate' (or evolved adaptations) that guide learning and development, being present more or less in all animals, including humans. Piaget's interest in children's cognitive development arose when he created tests for investigating intelligence. He discovered that children made systematical kinds of errors, and recognized that these patterns appeared within quite fixed age spans. Piaget argued that children's intellect was the outcome of their own logic, which was not the same as the logical rules of adults [78]. In 1937 he published the famous book, *The Construction of Reality in the Child*,[9] in which he offers a model of how infants and children develop different concepts, such as space, time, objects and causality.

A central concept in Piaget's work is *schemata* (e.g. [77, 80]) or *action schemes* (e.g. [81]). These schemata/action schemes are the cognitive structures by which humans and other cognizers organize and adapt to the environment, which is similar to von Uexküll's functional circles (cf. [13]). However, it should be noted that these schemata are not physical or mental entities; they should rather be viewed as processes within the nervous system, which correspond to different concepts and categories. Moreover, schemata are reflexive by nature, and they can be inferred from mere reflex motor actions in newborns, like sucking and grasping behaviors [80]. Piaget supposed that an infant initially possesses very few schemata, but as the child grows and develops, these schemata progressively become more generalized and discriminated. This means, schemata are not fixed, since they change and become refined during ontogeny. For instance, a newborn infant sucks on nearly anything that is put into his/her mouth, but after a while the infant learns to differentiate between stimuli that can be associated with milk and stimuli that cannot. Hence, the infant has to develop various distinctive sucking schemata, one for milk producing stimuli, and another for non-milk producing stimuli [80]. However, these basic schemata should not be characterized as 'mental' or 'cognitive' in the traditional sense, rather they can be viewed as perception-action loops, functioning as a precursor of forthcoming 'mental' activities [77]. During the course of development, the basic reflexive schemata of the child improve, and become more differentiated and numerous, gradually resulting in a more complex network. All the schemata in an adult are derived from the basic and reflexive sensorimotoric ones. Thus, cognitive

[9] Originally published as *La Construction du Reel Chez l'Infant* in 1937, the English version appeared in 1954.

development is the process of construction and reconstruction of these dynamical and integrated schemata, and Piaget stated that "every schema is … coordinated with all other schemata and itself constitutes a totality of integrated parts" (Piaget, 1952, cited in [80], p. 16).

According to von Glasersfeld [81], the concept of schemata or action scheme is derived from the biological description of reflexes, but not limited to a 'simple' stimulus-response mechanism. Instead, this particular notion actually contains three crucial elements. Firstly, the identification of a certain situation, subsequently, a specific activity associated with the situation at hand, and finally the infant's subjective expectation that the performed activity actually produces the desired result. This means, the process of an infant's searching for the mother's breast, in order to find milk, should be viewed as a process of meaningful organization of agent-environment interaction (cf. [13]). von Glasersfeld [81] mentioned that Piaget considered "cognition as an instrument of adaptation, as a tool for fitting ourselves into the world of our experiences" (p. 14). Hence, cognition in Piaget's sense concerns the organization of the agent's sensorimotor experiences and interactions with the environment.

The processes of change and refinement of schemata are characterized as *assimilation* and *accommodation* (cf. e.g. [77, 78, 80]). On the one hand, assimilation is the mental process of integrating and adding new "perception-action loops" or conceptual substance into an existing schemata, allowing growth of the actual schemata. It should be noted that this means no radical change to the schemata itself. Accommodation, on the other hand, is the process of constructing new schemata or modifying an earlier existing one in order to fit the new stimuli. It is important to notice that the resulting schemata are the child's individual constructions, and not any integrated 'copies' of the external reality. The form and content of a certain schemata is determined by the individual's unique experiences of perception-action interactions with the environment. This means, the overall behavior of an agent reflects both assimilation and accommodation. The state of balance between assimilation and accommodation is called *equilibrium*, and equilibration is the process of moving from imbalance to balance. Equilibration is a self-regulatory internal mechanism, using the mechanisms of assimilation and accommodation, which allow external experiences to be incorporated into schemata. However, it should be noted that equilibrium is a temporary state, since new experiences might result in a state of disequilibrium, then triggering the processes of either assimilation or accommodation [77, 78, 80].

Wadsworth [80] points out that the relationship between action and knowledge is central in Piaget's genetic epistemology. In addition to the processes of accommodation and assimilation, physical and mental actions are also necessary for the development of intelligence. Moreover, Piaget viewed knowledge as a construction emerging from the child's active interactions. Fischer and Kaplan [78] paraphrased Piaget as follows:

> I am a constructivist. I think that knowledge is a matter of constant, new construction, by its interaction with reality, and that it is not pre-formed. There is a continuous creativity (p. 681).

Piaget identified three kinds of knowledge, each of them resulting from the child's interactions with the environment, namely *physical*, *logical-mathematical*, and *social knowledge* [80]. Physical knowledge is characterized as the subject's knowledge of events and concrete objects, which is derived from the child's sensorimotoric manipulations of these objects. Through these actions the child *discovers* and *constructs* physical knowledge about the shape, size, weight, texture, of a certain object such as a pot, for example. Logical-mathematical knowledge is the result of mental actions (thinking) *about* experience with objects. It should be noted that the child *invents* this form of knowledge rather than discovers it as with physical knowledge. However, it is important to note that the child's inventions are derived from his/her earlier sensorimotor actions with objects. An example of logical-mathematical knowledge is number concepts, which the child develops by manipulating different arrangements of objects, materials and sets. In this form of knowledge, the objects themselves serve as a medium for the child's inventions, rather than being the focus of interest. The last form of knowledge is social knowledge, which is constructed from the child's interactions with other people. Examples of social knowledge include social and cultural conventions of how to behave in certain situations, e.g. rules, laws, values, morals, ethics and language systems. As a consequence of different cultural settings, various forms of social knowledge exist. From the beginning, the infant is more dependent on sensorimotoric experience, before he/she is able to possess the 'power' of symbolic representation in the form of language. The initial and basic schemata are a kind of sensorimotor representations of objects, and later on these sensorimotor actions become more conceptual in their form [80]. Broadly speaking, the child can only construct knowledge by directly *acting* on objects or *interacting* with others, not by viewing other people manipulating these objects or telling the child about their characteristics. Hence, *constructed* knowledge is the result of the child's subjective first-hand experiences of interactions with objects and other people.

Piaget identified four major cognitive developmental stages that correspond to qualitative differences in intellectual development (cf. e.g. [77, 78, 80, 82, 83]). These stages should not be viewed as distinct steps on a stairway, but rather as a successive and cumulative process. Piaget viewed cognitive development as a continuum, wherein the latter stages are derived from previous ones, being incorporated and transformed to a 'higher' level, and each stage in turn consists of several substages. Piaget characterized the main four stages as follows (cf. e.g. [80, 82, 83]):

1. The stage of sensorimotoric intelligence (0–2 years).
2. The stage of preoperational thought (2–7 years).
3. The stage of concrete operations (7–11 years).
4. The stage of formal operations (11–15 years).

During the first stage 'cognition' is primarily characterized as *sensorimotor intelligence*, and it addresses no conceptual thinking, but the child's behavior begins to be goal-directed. The cognitive development is mainly focused on constructing and discriminating different schemata, building concepts about how reality works. In the next stage, *preoperational thought*, the child is able to develop different representational systems like language and other conceptual systems. Piaget regarded language as a demonstration of the symbolic function, displaying a certain stage of mental development. In fact, Piaget rather viewed language as an aid for intellectual development, but not as a necessary means for a producer of intelligence [80]. The child's reasoning and logical ability is limited to tasks directly at hand, being dominated by perception, and viewed as pre-logical. In the *concrete operations stage*, the child begins to apply more formal logical thought to real problems that he or she encounters directly. It is in the final stage that the child has developed the 'highest' form of reasoning and can apply *logical reasoning* to all kinds of problems, and is capable of hypothetical reason and abstract thought. Hence, the child has developed the most advanced form of cognitive functioning. It should be noted that the age spans are not inflexible, but should rather be viewed as normative, although Piaget believed that the order is fixed and regression from one stage to another would not occur. Piaget also claimed his theory of cognitive development is universal, as a consequence of the logical formalization of his theory. The basic organizational force of intellectual development is logic, and this is highlighted in the four stages, characterizing different forms of logical thinking [78–80, 82, 83].

In order to move within and between these stages, Piaget identified four important factors for cognitive development, namely *maturation*, *active experience*, *social interaction*, and *equilibration* (cf. e.g. [80]). Maturation and heredity play a role in intellectual development, setting a wide constraint for the developmental process. The importance of active experience is already addressed in this section, and it is central for assimilation and accommodation. Social interaction is characterized as the interchange of ideas among individuals, and it is of major importance for the development of social knowledge. According to Sinha and Jensen [79], it is often argued that Piaget neglected the social dimension, which they, however, consider a common misunderstanding. They point out that he actually stressed the social dimension as an essential factor for the development of cognition, as stated, for example, in the quote below:

> Whether we study children in Geneva, Paris, New York or Moscow, in the mountains of Iran or the heart of Africa, or on an island in the Pacific, we observe everywhere certain ways of conducting social exchange between children, or between children and adults, which act through their functioning alone, regardless of the context of information handed down through education. In all environments, individuals ask questions, work together, discuss, oppose things and so on; and this constant exchange between individuals takes place throughout the whole of development according to a process of socialization which involves the social life of children among themselves as much as their relationships with other children or adults of all ages (Piaget, 1972, cited from [79], p. 19).

According to Sinha and Jensen [79], Piaget supposed that socio-cultural factors could either accelerate or retard the developmental process. He actually admitted that in some cultural settings the final stage of formal operational thinking might not emerge in the individuals. This means, Piaget viewed the social-cultural factors as a necessary and sometimes limiting condition, which could only influence the *speed*, not the direction, to the terminal point of (logical) cognitive development. The final important factor of intellectual development is the previously mentioned mechanism of *equilibration*, which functions as a coordinator and self-regulator between the three other factors during cognitive development.

Piaget's ideas initially did not fall on receptive ground outside the French-speaking community. Possible reasons for this were that he was only published in French, and the dominance of the behavioristic era in the United States [78]. However, as Vauclair and Perret [84] pointed out, it is amazing to note that Piaget already in 1955 founded the International Center for Genetic Epistemology (ICGE) in Geneva, financed by the Rockefeller Foundation. Moreover, Piaget was positive towards multidisciplinary research, and can be regarded as a forerunner to the interdisciplinary approach in modern cognitive science. His most significant contribution is the claim that cognitive changes are the outcome of a developmental process. Sinha and Jensen [79] pointed out that while his stages are not central in today's developmental theories, his constructivistic, biological, and epigenetical ideas really are.

However, it should also be mentioned that Piaget's theory has been criticized heavily. The main criticisms have focused on his extensive research on his own children, his use of methodologically flawed experiments, his inaccurately corresponding age-spans, and his failure to explain the mechanisms behind the process of equilibration (cf. e.g. [80, 83]). Boden [77] noted that Piaget actually underestimated children's abilities and innate capabilities, both initially and later on during development. Another main issue is that his theory is based on intellectual 'ideals' of the Western tradition, not paying enough attention to cultural differences in cognitive development, as illustrated by his claim that his theory was universal [85]. Another issue is his neglect of the relational aspect of cognition, an issue that Vygotsky and Mead much more strongly emphasized.

2.4.4 The Cultural and Historical Approach of Vygotsky

The Russian scholar Lev Vygotsky (1896–1934) viewed individual cognition and intelligence as culturally based, grounding his theory in the cultural history of the human species and the child's interactions with other people in its particular culture. Unfortunately, he died at the age of 37 in 1934, and his work did not reach the Western world until 1962, when the first public translation in English appeared. One cause for this delay is probably the fact that Vygotsky's work was banned in the Soviet Union from the mid-1930s to the mid-1950s. According to Kozulin [86], Vygotsky was initially active during an era when Russian psychology was dominated by behavioristic reflex theories, proposed by, e.g., Pavlov and Bekhterev. Besides contemporary Russian psychology, Vygotsky was inspired by the work of Hegel and Darwin, and was familiar with Gestalt psychologists such as Koffka, Buhler, and Köhler, as well as the early work of Piaget. However, Vygotsky himself was critical of both behaviorism and Gestalt psychology; he argued that these studies, in their "zoological models" removed the essential differences between human and animal intelligence. Vygotsky [87] therefore claimed that human intelligence was "more than a leather sack filled with reflexes" (p. 9), arguing that the existing psychological

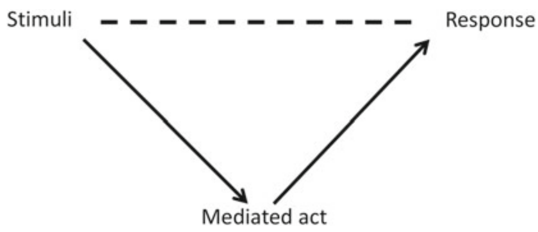

Fig. 2.1 The organization of higher behavior via a mediated act

theories had failed, since they were not capable of explaining all the structures of human behavior. Instead, he searched for a psychological theory that would describe the development of the abilities that are exclusively human. He claimed this could only succeed if all dimensions of the human mind were analyzed, but not in the form of introspectionism. Vygotsky [87] was critical of this ‘mentalistic’ convention, since it, in his opinion, confined itself through circular reasoning into which states of consciousness were ‘explained’ by the term of consciousness. As an alternative, he argued that if consciousness is taken as the subject of study, then its explanation must be sought in some other dimension of reality. Vygotsky proposed that socially meaningful activities play this role as a ‘producer’ of consciousness, arguing that the individual mind is constructed from the outside, through interactions with other people. In his own words [87]:

> The mechanism of social behavior and the mechanism of consciousness are the same … We are aware of ourselves in that we are aware of others; and in an analogous manner, we are aware of others because in our relationship to ourselves we are the same as others in their relationship to us (p. 29).

This means, the nature of individual human intelligence is, according to Vygotsky, developed through interactions with the environment in general, and more precisely it is the result of social interactions with other human beings.

Vygotsky[10] [88] distinguished between *elementary* and *higher mental functions*. He asserted that our elementary mental functions had to be those functions that were genetically innate and existed both in humans and (other) animals. These elementary or natural mental functions include for example, simple memory, perception and attention. These mental functions are controlled by the recognition of co-occurring stimuli in the environment, which Vygotsky referred to as *signalization*. According to Vygotsky, the higher or cultural mental functions are *exclusively human* and emerge dynamically through radical transformations of the lower ones. In elementary functions there is a direct link between a stimulus in the environment and a response from the creature, which Vygotsky expressed by a stimuli response formula [88]. However, for a higher mental function the structure differs significantly, since it involves an *intermediate link* between the stimulus and the response, as illustrated in Fig. 2.1.

Vygotsky claimed that this type of organization, via a mediated act, is fundamental to all higher cognitive processes, although typically in a much more complicated

[10] Originally published in Russian 1934.

structure than illustrated above. The intermediate link involves the psychological tool which is 'drawn into' the cognitive operation to fulfill a special function, namely creating an altered relation between stimulus and response [88]. The higher mental functions lie *outside* the individual, in the form of psychological tools and interpersonal relations. The lower functions do not disappear in the 'developed' or 'enculturated' mind, but undergo some re-organizations according to particular forms of human cultural activity [86].

Vygotsky particularly focused on the factors that distinguish between elementary and higher mental functions. Primarily he mentioned the shift of control from the environment (*signalization*) to the individual's voluntary regulation of his/her behavior. He subsequently claimed that social origins and nature are the driving forces of higher mental abilities, as well as the use of *psychological tools* that mediate higher mental functions. For example, Vygotsky [88, 89] argued that such a simple operation as tying a knot in a handkerchief to function as a memory cue altered the psychological construction of remembering. As a result, the memory process was extended beyond the biological inherited factors; the incorporation of artificial or self-generated stimuli in the form of psychological tools was the key difference between animal and human behavior. He maintained that previously in human evolution, humanlike ancestors developed simple tools, and this invention led to a shift of behavior, resulting in an important change in the pattern of thinking. Vygotsky called this process of conveying meaning to arbitrary stimuli as *signification* [88, 89]. He argued that (other) animals were not capable of performing such operations, which demarcate the starting point of human intelligence.

The invention, and use of arbitrary stimuli as psychological tools to perform advanced cognitive 'tasks' such as remembering, decision-making, etcetera is according to Vygotsky [88, 89], analogous to the human invention and use of technical tools such as hammers, saws, spades and ploughs. However, this analogy has significant differences, because the two separate activities have crucial distinctions [88, 89]. The basic foundation in the analogy between a psychological tool and a technical one lies in their *mediating function*, which characterizes both of them. Consequently, they can be included in the same category, from a psychological standpoint. Vygotsky argued that the essence of the use of psychological tools for mediated activity is they influence and have an effect on human behavior, since actions conducted with these psychological tools create thoughts [88]. In 1933 he stated "the central fact about our psychology is the fact of mediation" (Vygotsky, quoted from [90], p. 15).

The most important distinction between a technical tool and a psychological one lies in how they affect human behavior. The technical tool is *externally oriented*, towards changing objects, whereas psychological tools are *internally oriented*, by changing ways of thinking, controlling, regulating, and organizing behavior. As a consequence, both technical and psychological tools transform cognition. The psychological tools bridge the gap between elementary and higher mental functions, and they include "various systems for counting; mnemonic techniques; algebraic symbol systems; works of art; writing; diagrams; maps, and technical drawings; all sort of conventional signs, and so on" (Vygotsky, quoted in [85], p. 252). Of the psychological tools, mediating our thoughts, feelings and behavior, he considered language the most significant. Vygotsky [88, 91] stressed that the primary function of language, in the form of speech, is a device for social contact, and interpersonal communication, influencing other people. Later, this social speech transforms and becomes *egocentric speech*, which internalizes social speech for the child's own ends. Vygotsky [91] argued that this egocentric speech is a shift from social speech (between people) to inner speech, which 'goes' inward into the mind, by directing our own thinking. Consequently, the interpersonal becomes intrapersonal, and 'actions' with this special psychological tool create thought. Thus language liberates us from our immediate perceptual experience and allows us to also represent the past, the future and the un-present. Thinking and language are dynamically related, since understanding and producing language are processes that transform the process of thinking.

As a result of his analysis of the differences between animal and human behavior, resulting in elementary and higher functions, Vygotsky identified two different influences on psychological development, namely *biological factors* and *sociohistorical factors* [88]. According to Vygotsky, biological factors are part of our ontogenetic development, and incorporate the development of the physiological body. These biological factors control the initial months of life in infants, responsible for the development of perception, basic memory and spontaneous attention. Vygotsky called the emergence of these elementary mental functions *natural* (or primitive) development. The second line of development is *sociohistorical*, and it appeared with the invention and use of culturally based psychological tools (signification) in primitive humans. These tools function as 'regulators' of human *social* behavior, and especially language is an important 'organizer', both in the form of speech and written text. The line of sociohistorical development separate human behavior from animal behavior, as well as also having a significant role in the cognitive development of the individual child, since the child literally is born into the psychological tool systems of its particular culture. Vygotsky characterized the importance of these two lines of development for individual intelligence as follows:

> The cultural development of the child is characterized first by the fact that it transpires under conditions of dynamic organic changes. Cultural development is superimposed on the process of growth, maturation, and the organic development of the child: It forms a single whole with these processes. It is only through abstraction that we can separate one set of processes from another.
>
> The growth of the normal child into civilization usually involves a fusion with the processes of organic maturation. Both planes of development - the natural and the cultural - coincide and mingle with each other. The two lines of change interpenetrate one another and essentially form a single line of sociobiological formation of the child's personality (Vygotsky, quoted from [90], p. 41).

Hence, the cognitive abilities of an 'enculturated' adult human are the product of these processes of cognitive development, in which 'primitive' and 'immature' humans are transformed into cultural ones. In simple terms, the child initially has to learn the particular psychological tools of its culture, and then learns how to use them to master and control its own behavior. This transformation process, from elementary (or natural) mental functions to more complex higher functions is described (not explained) by two key principles, namely, the process of *signification* (using psychological tools), and a principle referred to as the *general law of cultural development* [90]. The essence of the latter is as follows:

> Every function in the childs development appears twice: first, on the social level, and later, on the individual level; first, *between* people (*interpsychological*), and then inside the child (*intrapsychological*) … All the higher functions originate as actual relations between human individuals … *The transformation of an interpersonal process into an intrapersonal one is the result of a long series of developmental events* … The internalisation of socially rooted and historically developed activities is the distinguishing feature of human activity, the basis of the qualitative leap from animal to human psychology (Vygotsky [88], pp. 56–57, original emphases).

Vygotsky called this process of transforming an interpersonal process (human-to-human interaction) into an intrapersonal one *internalization* [88]. To illustrate the essential role of social interactions during this transformation process Vygotsky used the example of the development of pointing in the child. He claimed that initially it is only a simple and incomplete grasping movement directed towards a desired object, only represented by the child's reaching and grasping movement, and nothing more. When the caretaker comes to help the child, the meaning of the gesture situation itself changes, by obtaining another meaning, as the child's failed reaching attempt provokes a reaction, not from the desired object, but from another person. The individual movement 'in itself' becomes a gesture 'for-others'. The caretaker in this case interprets the child's grasping/reaching movement as a kind of pointing gesture, resulting in a socially meaningful communicative act, whereas the child itself at the moment is not aware of its communication ability. However, after a while the child becomes aware of the communicative function of its movements, and then begins addressing its gestures towards other people, rather than the object of interest that was its primary focus initially. Thus, "*[t]he grasping movement changes to the act of pointing*" (Vygotsky [88], p. 56). As Kozulin [86] pointed out, it is essential to note that the child itself is the last person who 'consciously' grasps the 'new' meaning of its own pointing gesture.

Another central concept in Vygotsky's theory is the so-called *zone of proximal development* (ZPD), which is related to the process of internalization in the child, transforming interpersonal functions into intrapersonal ones. It is in the zone of proximal development that the child learns, through social interactions, how to use the tools available, especially the psychological ones. Vygotsky [88, 91] noticed that when a caretaker gives meaning to the child's interaction, when the child is unable to do so for itself, the child is working in the zone of proximal development, which Vygotsky characterized as follows Vygotsky [88]:

> It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (p. 86).

The caretaker realizes the child's achievement by means of hints, explanations, encouragements, regulating and controlling the child's focus of attention and so on. Vygotsky [88] also related *imitation* and *learning* to the zone of proximal development. He argued that a child can merely imitate what is within its zone of proximal development, explaining if a caregiver presents a too advanced solution to a problem, the child did not grasp the solution, even when the solution was presented repeatedly. The child can therefore only 'imitate' and adopt a solution to a problem or an activity if it is within the boundaries of the child's particular zone of proximal development. Moreover, Vygotsky argued that only humans possess a zone of proximal development [88]:

> A primate can learn a great deal through training by using its mechanical and mental skills, but it cannot be made more intelligent, that is, it cannot be taught to solve a variety of more advanced problems independently. For this reason animals are incapable of learning in the human sense of the term; *human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them* (p. 88, original emphasis).

Thus, according to Vygotsky, the 'mind' of the chimpanzee, for example, can never be developed and extended further than their biological heritage, since they lack a zone of proximal development. In other words, Vygotsky followed an evolutionary course stressing that both biological and social factors are responsible for higher mental functions. They are not controlled by conditioned reflexes or genetically determined, rather 'mediated actions'. However, the continuity ends here, as Vygotsky claimed that the process of mediated action was a uniquely human ability. However, it can be pointed out that Vygotsky misjudged animals because in his time relatively little was known about the richness of their social interactions and, perhaps even more importantly, the similarities of the biological mechanisms underlying human behavior and that of other animals (for a more detailed discussion, see Lindblom and Ziemke [92]). According to Davydov and Radzikhovskii [93], there is a major gulf between 'Vygotsky the psychologist' and 'Vygotsky the methodologist'. They point out that Vygotsky almost exclusively focused on the socio-cultural forces in his empirical studies, and that he neglected the biological line of development, especially the physical maturation in the child during its first years of life. They further argue that Vygotsky tended to view the biological factors as 'raw materials', which were then transformed by the socio-cultural forces, whereas he mentioned almost nothing about how changes in the biological factors may influence the socio-cultural ones. Wertsch [90], on the other hand, argued that Vygotsky himself was aware of the necessary, but not sufficient conditions provided by the biological factors, since he assumed that the natural factors play the major role in early ontogeny, and that the cultural forces take the leading role later on. Hence, Wertsch argues that Vygotsky did not view advanced cognition and thinking as the outcome of social factors alone, since he stated that "culture creates nothing; it only alters natural data in conformity with human goals" (Vygotsky, 1960, cited in [90], p. 47).

In sum, Vygotsky's theory of cognitive development particularly stresses that individual intelligence emerges as a result of biological factors (embodiment, one might say in today's terms) that interact with a physical and especially a social environment (in today's terms: situatedness) through a developmental process. Interestingly, whereas behaviorism had a great impact within psychology in the United States by ignoring any mental content, the Vygotskyan approach and its successors took a totally different approach already during the 1930 s and onwards, stressing the role of mediation, embodiment and situatedness for the development of higher mental functions.

2.4.5 Dewey and Bartlett

Two scholars who are usually not explicitly associated with theories of embodied and situated cognition (for exceptions see Clancey [2], and Johnson [94]), but who in my opinion deserve more attention than they so far have received are presented here. The reasons for mentioning them are that John Dewey's and, in particular, Mead's ideas (presented in the following section) have some interesting similarities with Vygotsky, since they both stressed the biological and social nature of intelligence. Moreover, Sir Frederic Bartlett emphasized the constructive aspect of cognition, and his *schema theory* has had a great impact on the role of internal representations in the forthcoming field of cognitive science. However, his ideas of schema theory focused on cultural and social aspects, which were largely ignored in the theories proposed by classical cognitive science.

The American philosopher John Dewey (1859–1952) tried to elaborate a non-dualistic view between knowledge and the world, arguing that it is not possible to go beyond ourselves in order to see the 'real' world (cf. e.g. [95]). Hence, it is not possible to think of the world without describing it from the subjective point of view, and this line of argument is the basic foundation of all his work. According to Marsh [96], Dewey can be considered as the first "ghost-buster", in his efforts to provide an anti-dualistic/non-Cartesian philosophy of mind. Furthermore, Field [95] points out that Dewey tried to elaborate a new 'theory of knowledge', arguing that the traditional epistemologies, such as rationalists and empiricists, had drawn a too sharp distinction between thought and knowledge, since thought was supposed to exist apart from the world [95]. Dewey's theory rejected these traditional assumptions, and he argued that knowledge should be viewed in a practical way, instead of striving after the 'figment of your imagination' of objective knowledge [6].

According to Field, Dewey was influenced by the American philospher and psychologist William James and the German philosopher Friedrich Hegel, but his primary source of inspiration was Darwin's theory of natural selection. Dewey supposed that Darwin's idea had swept away 'supernatural' explanations of the origins of species, since the theory of natural selection stressed that living organisms are the product of a natural and sequential process of adaptation to the environment [95]. Consequently, Dewey proposed a naturalistic approach to a 'theory of knowledge', which considered the development of knowledge as a process of active human adaptations to changing environmental conditions. Contrary to traditional approaches of 'knowledge', Dewey described thought genetically, as the *product* of the interaction between organism and environment, and knowledge was supposed to have a 'practical instrumentality' in the guidance and control of that interaction [95]. As a result, Dewey used the term "instrumentalism" for his new approach. The first significant application of this 'naturalistic understanding' was offered in his seminal article '*The reflex arc concept in psychology*' in 1896 [35], previously presented in more detail in Sect. 2.2. In that article, he attacked the basic units of analysis within behavioral psychology, namely 'stimulus' and 'response'.

Broadly speaking, behavior was at that time described as a conversion of a response to a certain stimulus, but Dewey argued that this description is partial, since it only explained what happens between the reception of a stimulus and the generation of an action. Instead, Dewey supposed that behavior should rather be viewed as a control process, which coordinates ongoing activity (cf. e.g. [2, 7]). He maintained that perception and action are closely coupled, and he called this coupling "sensory-motor coordination". This close coupling is especially present in contemporary work in 'active vision' (cf. e.g. [7]). Furthermore, there is evidence that vision should not be viewed as passive information processing, instead it is an active and integrated sensorimotor outcome. Current research on active vision is an instantiation of the general idea of Dewey's claim that perception and action are closely linked (cf. e.g. [2, 7]).

According to Field [95], Dewey proposed 1928 in his book *Experience and Nature* [97] that the mind has a social origin, and that the human individual is initially a social being. Hence, he viewed the mind as an emergent function which has its foundation in natural processes, shaped through interactions between human beings and the world in which they live. Dewey's ideas can be interpreted in today's terms as being situated and/or embodied, and Pfeifer and Scheier [7] point out that the approach of 'sensory-motor coordination' is of fundamental importance for an embodied cognitive science. Instead of viewing different forms of intelligent behavior (e.g. memory, perception, and learning) as 'sense-model-act' series, the principle of 'sensory-motor coordination' offers an alternative explanation. However, despite the fact that the work of Dewey is well-known in many scientific areas in general, his work is to a large extent ignored in the cognitive science literature, although his name is mentioned quite often within the areas of learning and education. Similarly, Rockwell [98] argues that Dewey's work is grossly disregarded in the situated/embodied approaches to mind, albeit he is a fore runner to these ideas. Dewey's work, for instance, is only typically mentioned in a few sporadic lines or not at all (cf. e.g. [1, 6, 49, 69, 99]). Although his work has strong similarities with today's embodied and situated theories of cognition, particularly Pfeifer and Scheier [7], Clancey [2], Johnson [94] as well as Rockwell [98] strongly address Dewey's ideas in depth from an embodied/situated perspective of cognition.

Sir Frederic Bartlett (1886–1969) was an experimental psychologist active in Great Britain, and he is most well known for his work on memory which he presented in his landmark book, *Remembering—a Study in Experimental Psychology and Social Psychology* [100]. In that book he described his studies on memory and presented the foundation for his theory of schema, which later influenced the fields of cognitive science and psychology [101]. Roediger [101] points out that the main theme in Bartlett's book is to emphasize the constructive nature of cognition. In one of Bartlett's most well-known experiments, the subjects read a native American folktale called *The War of the Ghosts*, and then are encouraged to retell the story at different time intervals. Bartlett recognized that the subjects changed details in the story that they did not understand, since the cultural context of the story was quite different from their own socio-cultural background. Bartlett coined the term "effort after meaning" in order to refer to the subject's actual behavior when they were confronted with elements that they did not understand in the foreign folktale.

As a result of these observations, Bartlett suggested that memory is a subjective process of reconstruction, which in fact is a highly social act, and the idea for schema theory was born [79]. Roediger [101] paraphrases Bartlett's conclusion that "the most general characteristic of the whole group of experiments was the persistence, for any single subject, of the form of his first reproduction" and the utilization "of a general form, order and arrangement of material seems to be dominant, both in initial reception and in subsequent remembering" (p. 320). Bartlett denoted the 'general form' that humans encoded and remembered their experiences as "schema". According to Sinha and Jensen [79], Bartlett considered the concept of schema as both a common principle of cognitive organization, and as a unit of analysis for revealing social and cultural variations in different models of the world. Moreover, Saito [102] mentions that Bartlett suggested that more advanced cognitive processes, like remembering and thinking for instance, are active, selective and constructive processes, which are formed and influenced to a great extent by social factors.

Clancey [2] points out that Bartlett is usually credited for introducing the concept of schema as traditionally used in the descriptive models of cognitive science and AI. However, he notes that Bartlett himself strongly argued *against* prototypical descriptions of object and the term schema as such, since it could be viewed as something persistent, and not stressing its constructive nature. As Clancey reveals, the strong emphasis on representations during the 1970s and 1980s generally missed Bartlett's point of view, and the fact that "Bartlett was striving for a psychological theory that viewed the organism as a whole, within its everyday experience of perceiving and acting in some context" ([2], p. 48).

Saito [102] points out that Bartlett's phylogenetic explanation of cognition has similarities with the theories of Piaget and Vygotsky, since Bartlett also stressed a "tripartite" origin of cognition, namely *biological*, *psychological* and *social* factors. Saito notes that including the social perspective of cognition does not automatically rule out the individual aspect, the real problem actually starts when taking an 'either-or' position. Instead, Saito proposes an approach that encompasses all these significant factors, taking a multi-level perspective. As a departing point for such a hypothetical approach, Saito [102] reviews Bartlett's [100, 103] work on the social foundation of cognition. His conclusion is that previous reviews of Bartlett's work concerning social origins do not pay enough attention to Bartlett's multi-level analysis which, in his opinion, emphasizes an embodied mind approach.

2.4.6 Mead's Theory of the Socially Interactive Mind

Finally, the American philosopher George Herbert Mead (1863–1931) is considered one of the founders of Pragmatism as well as having great influence in the area of social psychology [104]. However, his most significant contribution, from a cognitive viewpoint, is the work on the role of social interaction for the emergence of mind and consciousness. Similarly, Lewis [105] stressed that of utmost importance in Mead's theory of the interactive mind is the opinion that knowledge of the self and knowledge of others are interdependent.

Mead described in *Mind, Self and Society* [106] how the individual mind and self emerges from social interaction, in particular, he stressed that individual cognition is exceptionally and deeply social. In other words, according to Mead, social practice is prior to the structures and processes of individual cognition. Given that mind arises from social interaction and communication, it cannot be explained independently of these processes. Like the mind, the self is also socially emergent, which means that the individual self is the *outcome* of social interaction and not the precondition for social interaction and cognition. This means that Mead's theory of the self is in contrast to individualistic approaches of the self, which assume priority of selves to the social process [104, 107]. For instance, Mead [106] pointed out that:

> The self is something which has a development; it is not initially there, at birth, but arises in the process of social experience and activity, that is, develops in the given individual as a result of his relations to that process as a whole and to other individuals within that process (p. 135).

Mead [106] considered the process of communication as involving two stages, namely *conversation of gestures* and *conversation of significant gestures*. It should be strongly emphasized that Mead, in both cases, took for granted the social context within which two or more individuals interact with one another. In general, conversations of gestures are manual gestures, bodily postures, facial expressions and so on. According to Cronk [104], a famous example of this kind of communication is the dog-fight, in which Mead [106] described how two dogs interact with each other through bodily expressions.

> The act of each dog becomes the stimulus to the other dog for his response. There is then a relationship between these two; and as the act is responded to by the other dog, it, in turn, undergoes change. The very fact that the dog is ready to attack another becomes a stimulus to the other dog to change his own position or his own attitude. He has no sooner done this than the change of attitude in the second dog in turn causes the first dog to change his attitude. We have here a conversation of gestures. They are not, however, gestures in the sense that they are significant. We do not assume that the dog says to himself, "If the animal comes from this direction he is going to spring at my throat and I will turn in such a way". What does take place is an actual change in his own position due to the direction of the approach of the other dog (pp. 42–43).

Taken together, communication occurs between the dogs without any awareness of the responses that the gestures generate in the other dog because neither one nor the other individual dog is aware of the reactions of the other to its gestures. This means, the dog is unable to respond to its own gestures from the standpoint of others. Despite the fact that the individual participants in the conversation of gestures interact socially, they obviously do not know that they are communicating [104]. In other words, the phase of conversation of gestures is considered *unconscious* communication in Mead's view. *Conversation of significant gestures*, however, is communication through human language, which Mead mostly referred to as vocal gestures. He maintained language is the means of social interaction by *significant symbols*. The crucial characteristic of a significant symbol is its ability to function correspondingly to both (i) *the individual making the vocal gesture*, and to (ii) *the response called out in others to whom the vocal gesture is directed*. Furthermore, Mead's approach is developmental, because it is from the conversation of gestures that human language arises in the form of *conscious communication*. Thus, more advanced forms of communication emerge from more or less basic forms of social interaction. In humans, language exceeds but does not eliminate the conversation of gestures and characterizes the transition from *non-significant* to *significant interaction* [104, 107].

Gillespie [107] argues that 'taking the attitude of the other' is the crucial characteristic of the significant symbol. This means, the significant symbol is not only a *shared* singular perspective, but needs the self to take the attitude of *both* the self and the other at the same time. In other words, it functions as a kind of social duality beyond mere sharing between individuals. Gillespie proposes that this 'social duality' is accomplished by Mead through the social act. In order to develop the argument, we return to the previously presented reflex arc by Dewey. Broadly speaking, Mead's social act is a reply to the dualistic conception of interaction that dates back to Descartes (see Sect. 2.1) as well as an elaboration of the Deweyan act. Mead claimed that the Deweyan act is incomplete since it only deals with subject-object interaction, and is therefore unable to shed any light on mind and consciousness. Instead, Mead focused on subject-subject interaction, which then became the breakthrough in his work. Gillespie [107] denotes Mead's approach to the feedback theory of consciousness, because it is the feedback we receive from others that establishes the meaning of our actions, which in turn generates consciousness.[11] Citing Mead, Gillespie writes [107]:

> We are conscious of our attitudes because they are responsible for the changes in the conduct of other individuals. A man's reaction toward weather conditions has no influence upon the weather itself. It is of importance for the success of his conduct that he should be conscious not of his own habits of response, but the signs of rain or fair weather. Successful social conduct brings one into a field within which consciousness of one's own attitudes helps toward the control of the conduct of others (Mead, 1910 in [107], p. 25).

In accord with this remark, we return to Vygotsky's pointing example, in which the child's reaching attempt is goal directed, but notably the child initially has no awareness of the act itself, since only the desired object is meaningful, and not the act of reaching. However, Vygotsky then introduced the mother, and Gillespie emphasizes that from her perspective, the reaching act is meaningful. Hence, through social feedback, the mother changes the grasping attempt into pointing, but it should be stressed that the social feedback does not imply the child is yet able to take the perspective of the other, in this case the mother. Accordingly, the mother's attitude

[11] Although this stance has similarities with Vygostky's ideas, Gillespie mentions that this social 'mirror' approach dates back to the work of Adam Smith (1759, in [107]) by which Mead might have been inspired.

toward the child, engaged in the Deweyan act with some object, provides the necessary social feedback. Therefore, there is a distinct shift from a *dyadic* to a *triadic* model of interaction, and meaning emerges from these subject-subject interactions. Thus, according to Mead [106], meaning arises within social interaction between individuals, and is not pre-given per se. Furthermore, conversation of significant (vocal) gestures functions both externally, i.e. between different individuals, and internally, i.e. between the individual and oneself. Most generally, social cognition is always *relational*, and Mead's act is a *social* act. Hence, the relational nature of interaction proposed by Mead (as well as Vygotsky), is the significant difference between the Deweyan and the Meadian acts.

However, according to Gillespie [107], Mead himself came to reject this view, i.e. subject-subject interaction for two reasons. On the one hand, he was discontent with the stance that the living and animate world offers more feedback than the physical and inanimate world. On the other hand, non-human animals, even social insects, receive feedback from each other, and yet do not appear to have either consciousness or mind. For these reasons, he concluded that feedback per se does not lead to consciousness or mind, arguing that a dog can be taught to 'point' with its paw toward food without the dog being aware of the meaning of pointing. However, the core problem with the social feedback theory is its disguise of the subject-object model of interaction, because the other is regarded as a 'pseudo other', since it nevertheless can be an object or mechanical device [107]. Accordingly, the major focus is still on the actor, and the other is not endowed with any independent perspective. The crucial point is the incorporation of the 'perspective of the other' into the analysis of the subject-subject interaction, which is then referred to as *subject-subject relation* [107]. It is here that Mead's concept of 'taking the attitude/role of the other' becomes relevant in order to portray the significance of Mead's social act.

Most generally, Gillespie points out there are two related insights in Mead's work on the emergence of consciousness and self-mediation. Firstly, Mead defined consciousness as becoming other to oneself, and it is only through becoming 'other to self' that this reflexive self-mediation of consciousness is able to occur. Secondly, Mead recognized, as Gillespie puts it [107], "self is already other from the perspective of other within social interaction, and thus if self could take the attitude of the other (toward self) then we would have an explanation of consciousness" (p. 27). The critical point, however, as Gillespie stresses, is how the self can take the 'attitude of the other'.

The underlying problem here is the divergence of perspectives within social interaction, which is commonly mistakenly overlooked. Gillespie [107] emphasizes that "we automatically conceive of a situation from the perspectives of diverse participants simultaneously" (p. 27). Returning to Vygotsky's pointing example, the issue can be reformulated in the following way. Despite the fact that the actions of both child and mother partly comprise the other's situation, they are clearly engaged in different situations. How can the child then go beyond its own perspective and subsequently be able to experience the mother's situation, in which the child is 'the other'? The Meadian answer is the *social* act, which is a more specific kind of social interaction than the mere intertwining of two Deweyan acts. A Meadian *social act* refers to an interaction that has become an institution with established roles or positions (e.g., teacher/student, seller/buyer, cop/thief etc.). In this case the established positions are the mother and child, and these interactions are quite stable over time. According to Gillespie, the introduction of social structure and stability is fundamental for the shift from a socially interactive Deweyan act to the relational Median social act.

It is generally through the use of language that children begin to take the 'attitudes of others' toward themselves as a kind of perspective-taking. Given that human language functions as a crucial mechanism for mind, it also functions as the elementary foundation of the self. Mead [106] claimed:

> I know of no other form of behavior than the linguistic in which the individual is an object to himself, and, so far as I can see, the individual is not a self in the reflexive sense unless he is an object to himself. It is this fact that gives a critical importance to communication, since this is a type of behavior in which the individual does so respond to himself (p. 142).

According to Cronk [104] and Gillespie [107], Mead proposed that besides language, the social emergence of the self is further developed through two certain kinds of social interaction, namely *play*, and *game*. Crucial to the generation of self-consciousness in the play and games of children, as in linguistic interaction, is the process of *role-playing*. Cronk writes that through playing, children take the role of another and act *as though* they actually *were* the other (e.g., doctor, mother, house-keeper, Cinderella, and so on). Accordingly, in this kind of role-playing a child puts itself into a *single* role at a time, and a child's play experience of the other is a "specific other" [104]. The game, however, entails a more complex form of role-playing, since children must internalize the roles of *all* the others involved within the game. For example, in soccer, children must be aware of the roles of the referee as well as the different types of players, such as forward, back and goal keeper. Furthermore, children must also follow the rules of soccer which determine how the various roles in the game are determined to act. This configuration of "roles-organized-according-to-rules" results into Mead's "generalized other", in which the attitudes of all the participants form a symbolized unity. Cronk argues that self- consciousness in the full sense of the concept is achieved only when the individual child can perceive itself from the standpoint of the 'generalized other'. Taken together, these three kinds of symbolic interaction are regarded as the major pillars in Mead's socialization approach.

Cronk furthermore points out that even if the self is considered to emerge from symbolic interactions, it should not be regarded as a passive reflection. Instead, the individual's reaction to the social realm is an active process in which one decides what to do next from the attitudes of others. This does not imply that the behavior is in any way determined, i.e. there actually are two sides of the self [104, 106].

Mead [106] distinguished between 'me' and 'I' in order to explain how these aspects of self are related in conduct, namely the two phases that (i) reflect the attitude of the generalized other ('me'), and (ii) respond to the attitude of the generalized other ('I'). Most generally, 'I' is the momental awareness of the social 'me', because the 'I' of this moment is present in the 'me' in the next moment. Therefore, the 'I' functions as the novel and situational reply of the individual's 'me'. In addition, Cronk [104]

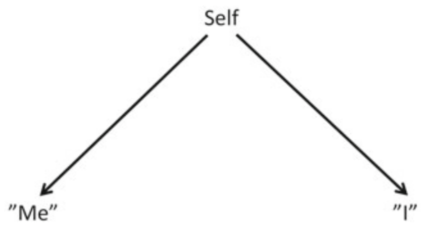

Fig. 2.2 The "me" is the social self, and the "I" is a response to the "me" in the construction of self

indicates there is a dialectical relationship between society and the individual, and this dialectic is enacted in terms of the polarity of the 'me' and the 'I'. In other words, the 'I' and the 'me' have a dynamic relation to one another, as illustrated in Fig. 2.2.

According to Varela [108], Harré elaborated Mead's theory of the social nature of mind and self, and introduced a discursive turn to Mead's 'taking the role of the other'. Harré (in [108]) considered the beginning of 'taking the role of the other' as the consequence of learning the linguistic practices of using the pronouns of one's culture, i.e., first, second, and third person. From this discursive turn, the second-person standpoint refers to Mead's the 'I' whereas the third-person standpoints refer to the 'me'. Furthermore, Harré stated that the interplay of the elements of self, the 'I', and the 'me', or first person pronominal practices, systematically vary across different cultures and languages, which implies that both the 'I' and the 'me' must be socially constructed. Consequently, there is cross-cultural evidence for the social emergence of self in favor of Mead's approach [108].

Thus, Mead considered the human mind as emerging out of the interaction of biological individuals in a social sphere. In particular, he stressed that mind should neither be considered as a 'substance' located in some transcendent realm nor existing as some event that takes place within the human physiology. According to Cronk [104], Mead rejected the traditional view of mind/body dualism as well as the attempt to explain mind merely in terms of physiological and neurological responses as in behaviorism. Indeed, Mead can be regarded as behavioristic in the sense that he claimed mind could be completely explained by behavioral terms, but only through the denial of the existence of a 'substantial' entity. Instead, he considered mind the natural function of human organisms, in which it was neither possible nor desirable to deny the existence of mind entirely. The human physiological organism is a necessary but not sufficient condition of mental processes, since the emergence of mind is dependent upon interaction between the human organism and its social environment. In particular, linguistic interaction is of crucial importance since there is no advanced mind or thought without language. Thus, mind is not reducible to the neurophysiology of the organic individual, but emerges in "the dynamic, ongoing social process" ([106], p. 7) that constitutes human experience.

Taken together, Mead's theory of the socially interactive mind and consciousness is highly compatible with today's embodied and situated approach of cognitive science. However, since Mead usually focused on vocal gestures and disregarded the role of manual ones, he failed to explicitly address other bodily aspects of social interactions, despite the fact that he considered humans as embodied biological persons in a social context (cf. [109]).

2.5 The Fall of Behaviorism and the Rise of a Science of Mind

Despite the serious criticisms raised against behaviorism from several of the researchers addressed earlier, behaviorism managed to be the leading approach in psychology and animal behavior, particularly in the United States, through the first half of the 20th century. However, its great impact started to decrease during the mid-1950s, with the following two major reasons responsible for that shift in interest. Firstly, ethologists challenged the equipotential assumption, and secondly, the advent of the computer confronted the anti-mentalistic assumption and paved the way for the 'cognitive revolution'.

However, some animal behaviorists had earlier obtained results that could not be explained merely in behaviorist terms. According to Gould and Gould [17], classical and operant conditionings do not suggest any evidence of higher mental processes or cognition in animals, although Tolman discovered a kind of latent learning in rats. His findings illustrated that animals are capable of performing novel behaviors by 'planning' and not only by 'goal-seeking' and trial-and-error learning. Tolman conducted the following experiment, already in 1948. A rat was allowed to walk around in a two-armed maze which had two ends; one black area end, and one white area, each containing food. The next day the rat was given an electric shock in a black box and on its release back into the maze the following day, it unmistakably ran towards the white area. The rat demonstrated it was able to link its previous, but unrelated experiences separated in time, place and context, by making a plan of a 'safe' run in the maze. This behavior could not be predicted or explained by behavioristic theories, and Tolman's finding was ignored and commonly scorned in his own research field. This neglect could be due to the fact that Tolman argued for some 'mental processing' underlying the rat's planned novel behavior, which he termed as a kind of "cognitive map" [17].

Although earlier scholars, like Tolman, for example, had assumed there was some mental content, animal researchers' greatest contribution to the fall of behaviorism was their demonstration of the incorrectness of the assumption of *equipotentality*. One of the strongest pieces of evidence was Breland and Breland's [110] discovery of biases in classical conditioning, revealing that 'innate' behaviors or tendencies overtook the conditioned or learnt behaviors, which they stated in their article *The misbehavior of organisms* as follows—obviously a reply to Skinner's [36] article *The behavior of organisms*.

> In our attempt to extend a behavioristically oriented approach to the engineering control of animal behavior by operant conditioning techniques, we have fought a running battle with the seditious notion of instinct … After 14 years of continuous conditioning and observation of thousands of animals, it is our reluctant conclusion that the behavior of any species cannot be adequately understood, predicted or controlled without knowledge of its instinctive patterns, evolutionary history, and echological niche (Breland and Breland, 1961, cited in [17], pp. 57–58).

Another study of crucial importance was performed by Garcia and Koelling [111]. This study revealed that it was difficult and perhaps impossible to teach a rat, using classical conditioning, to avoid flavored water, even if the rat received an electric shock. Furthermore, according to Gould and Gould [17], other animal studies demonstrated the impossibility of training rats to avoid electrical shocks by pressing a lever. The learning task was only successfully performed by the rats' natural flight behaviors of jumping or running-away. For example, rats were unable to associate feeding with flight behaviors and pigeons seemed to function in a similar way. Pigeons were able to learn to peck to obtain food, but could not learn to peck to avoid electric shocks. Hence, there seems to be some inherited constraints in the learning and behavioral repertoires of animals, since some kinds of tasks were easier to learn than others. Broadly speaking, these studies demonstrated that classical and operant conditioning are foiled by 'instincts', in the sense of functionally specialized adaptations in the animal's behavioral repertoire.

The role and relevance of social interactions became evident in Harlow's [112, 113] rather horrid experiments on infant rhesus monkeys. He separated the infants from their mother's shortly after birth and raised them in separate cages, in which artificial 'mothers' were placed, constructed of either wired or soft frames. Half of the rhesus monkeys were bottle fed from the wired dummy mother and the other half by the 'soft' dummy mother. The result revealed that the infant apes preferred the 'soft' dummy mother over the 'wired' mother, whether it offered food or not. Moreover, another study also indicated that growing up isolated, resulted in permanently socially impaired monkeys even as adults [114].

Despite the fact that a number of researchers criticized the mechanistic view of behavior, several machines were built, and they were mainly inspired by Loeb's work on tropism and Sherrington's work on reflexes [12, 115], in attempts to test the mechanical perspective. Additionally, advances in computer technology and influences from cybernetic theory resulted in efforts to build machines that illustrated some aspects of 'intelligent behavior'. As described by Bechtel et al. [1], cybernetics is characterized as the theory of 'control and communication in the animal and the machine', which is realized through a feedback mechanism. The feedback mechanism allows living organisms to maintain and steer themselves in dynamical environments, adjusting their internal components to external conditions and changes. According to Ziemke [12], Grey Walter's [44] work on constructing two artificial tortoises 'Elmer' and 'Elsie' around the 1950s, has had a strong impact on today's embodied AI research. Walter's work which was influenced by Loeb and Sherrington's notions of tropism and reflexes, demonstrated that the 'tortoises' were able to display phototaxis and 'hunger', i.e. they were able to recharge their batteries when necessary. Additionally, 'Elmer' and 'Elsie' had a small electronic 'nervous system', two 'sense reflexes' and two 'receptors', enabling them to be sensitive to light and 'touch' (being able to re-charge their batteries). The artificial tortoises were able to avoid obstacles, attracted to light, and constantly moved around except when re-charging their batteries, which was the only time when they were attracted to the bright light of the 'hutch'. As a result, these artificial creatures were able to display a number of different behaviors, and can be considered the "archetypes of biologically inspired robotics" [12]. Moreover, Grey Walter, who was also inspired by Pavlov's work on conditional reflexes, was the first person to developed and use reinforcement techniques for robot training. The experiments conducted by Grey Walter demonstrated that a rather simple learning mechanism made it possible for a robot to interact with its environment by adapting its behavioral repertoire [12].

Ziemke [12] points out that the early cybernetic and mechanistic attempts of building artificial creatures demonstrate that intelligent behavior was considered as the result of the interaction between an agent (artificial or natural) and its environment. Despite the fact that von Uexküll was very critical of the mechanistic view, the technical realizations of bringing forth successful behavior had general similarities with von Uexküll's work on functional circles and signs, which seemed to have a central role in that interaction. However, these early attempts of modeling intelligent behavior was gradually replaced with an approach that significantly separated internal representations from the external world—the computational paradigm. Consequently, the field of cybernetics largely died down as an approach for studying mental phenomena, but it can be viewed as a primary multidisciplinary effort in that direction [1, 69].

The death blow for behaviorism was the advent of the computer. An influential person in computer science was Alan Turing, who realized the idea of computational machines or a so-called 'Turing machine'. A Turing machine is an abstract automaton, and neither its physical realization is significant nor how it is physically executed. Its only significance is the process the machine performs. As a result, the concept of simulating human information processing in electronic computers emerged [7]. In Turing's classical paper *Computing machinery and intelligence* [116], he provided the basis for viewing the mind as computational, discrete and disembodied [117]. In the famous Turing test, the method for evaluating if a machine can think, the experimental set-up was totally disembodied. Furthermore, in order to investigate intelligence, Turing argued for the importance of drawing "a fairly sharp line" between human's physical and intellectual capacities claiming that his test should only address intellectual aspects, stated as follows:

> No engineer or chemist claims to be able to produce a material which is indistinguishable from the human skin. It is possible that at some time this might be done, but even supposing this invention available we should feel there was little point in trying to make a 'thinking machine' more human by dressing it up in such artificial flesh. The form in which we have set the problem reflects this fact in the condition which prevents the interrogator from seeing or touching the competitors, or hearing their voices (Turing, 1950, quoted in Wilson [117], p. 76).

Hence, the intellectual capacities addressed by Turing were highly disembodied, since it was obviously unnecessary for intelligence to be 'dressed up in flesh', which followed the Cartesian view of splitting the mind from the body [117]. However, in the conclusion of the same paper, Turing discussed the ability to build 'learning machines' (cf. [92]). He realized the difficulties of attempting to build an adult-like artificial mind and envisioned, as a possible alternative, so-called "child-machines", equipped with "the best sense organs that money can buy", whose education "could follow the normal teaching of a child":

> Instead of trying to produce a program to simulate the adult mind why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child-brain is something like a notebook as one buys from the stationers. Rather little mechanism, and lots of blank sheets … Our hope is that there is so little mechanism in the child-brain that something like it can easily be programmed. The amount of work in the education we can assume, as a first approximation, to be much the same as for the human child [116].

Turing himself carried out some experiments with simple 'child-machines', but after his death in 1954, most AI researchers focused on other approaches. Turing actually seemed to have considered neither human-like embodiment nor the full range of human social interactions as particularly crucial for the child-machine's mental development. With reference to the famous case of Helen Keller (cf. e.g. [118]), Turing argued that "[w]e need not be too concerned about the legs, eyes, and so on", as long as "communication in both directions between teacher and pupil can take place by some means or other". Furthermore, he envisioned the machine being tutored by humans, but also claimed "one could not send the creature to school without the other children making excessive fun of it". However, since the mid-1990s a number of researchers in situated/embodied AI and robotics have begun to take seriously the idea that the creation of artificially intelligent systems might require not only *physical* situatedness and embodiment, but also some form of child-like development in interaction with some *social* environment (cf. [92, 119]).

The dawn of the computer age and progress within information theory (e.g. [120]) took place at the same time, leading the way for the *information-processing metaphor of mind*. The computer was interpreted as evidence that internal representations and mental processes can occur in a physical device. As a result, the antimentalistic assumption in behaviorism was considered to be proven false, and the "new science of mind"—cognitive science was founded in 1956; the start of the so-called 'cognitive revolution'. AI was brought to light during the same time through its attempts to build 'intelligent machines' [6]. The inception of the so-called 'cognitive revolution' can be traced back to the *Symposium on Information Theory*, which took place at the Massachusetts Institute of Technology, in September 1956. The program during the symposium included, for example, the demonstration of Newell and Simon's 'Logic Theory Machine', which was an information processing system able to prove a complex logical theorem [6, 7]. According to Pfeifer and Scheier [7], Newell and Simon claimed they had built the first 'thinking-machine'. Moreover, the linguist Chomsky submitted a transformational grammar based on information theory, and Miller presented the 'magical number seven', which illustrated how the human short-term memory might function. According to Miller (cited in [1], p. 37) September, 1956 was when "cognitive science burst from the womb of cybernetics and became a recognizable, interdisciplinary adventure in its own right". Another important meeting in 1956 was the so-called 'Dartmouth conference', the aim of which was to discuss 'thinking machines', and many of the founding fathers of artificial intelligence were among the participants [6, 7]. Of particular importance to the fall of behaviorism was Chomsky's review [121] of Skinner's book *Verbal Behavior* [122]. Skinner suggested that language was also controlled by external stimuli, but was unable to fully explain this statement by behavioristic concepts. Chomsky presented a new theory of language based on linguistic transformation, and was able to illustrate how humans could produce totally 'new' utterances [7]. Broadly speaking, these new thinkers, together with several others, paid attention to what happened inside the 'skull', i.e. our internal processes, and reopened closed doors by modeling or conducting investigations of 'mentalistic' phenomenon that behaviorism had neglected.

As a result of the advent of the computer and the 'cognitive revolution', little attention, if any, in the following years was directed to studies in biology and animal behavior, because the new science of mind considered that those earlier attempts were wrong and misleading in the study of cognition [6]. Cognitive science, as a research field, studied 'higher' mental processes, which animals were assumed to lack, and researchers tended to relate studies on animal behavior in general and animal learning in particular with the 'horror' of behaviorism. Nevertheless, even if the behaviorists treated the mind as a 'black box', this box was in any case situated to some degree. It was placed in the surrounding world (although in an artificial environment) and reacted to it through real-time interactions. The early mechanistic and cybernetic models, for instance Grey Walter's artificial tortoises, which can be regarded as one of the precursors of the AI field, would be more or less completely ignored during the era of computationalism, and the same fate awaited theories that stressed agent-environment interaction [13]. In sum, the behaviorists can be regarded to having over-emphasized the role of the environment, while the forthcoming 'cognitivists' instead would under-emphasize its importance for intelligent behavior (cf. [25]). In Chap. 3 current theories and models of embodied cognition, to some degree, attempt to re-unit and/or integrate the two.

2.6 Computationalism: The Disembodied Paradigm

The computational paradigm was founded on two major hallmarks, namely *representations* and the *computer metaphor for mind*. This section presents the main theoretical characteristics of this paradigm, and illustrates how these major features became implemented and modeled in artificial systems. As a final point, some reasons are presented that try to explain why the computational paradigm became the dominant approach in the scientific study of mind on behalf of alternative theories.

As a consequence of the development of computer technology it became possible to realize Leibniz's notion that numbers could be designated to concepts, which could then be manipulated by formal rules, such as Boolean algebra. As a result, the concepts themselves could subsequently be manipulated, laying the foundation for the law of thoughts [1]. Accordingly, the role of representations was emphasized, and it was proposed that the 'mind' itself had mental (internal) models of the surrounding environment. A representation can be considered the mapping between the elements in the external world and the internal symbolic representations, and functions as an internal 'mirror' of the external environment. The concept of mental models goes back at least to Craik's work ([123], in [12]), who discussed the idea of having a 'small-scale model' of explicit knowledge about the world in the mind. Thus, thinking was viewed as the processing of those internal representations or symbols in the brain. As a result, researchers became influenced by formalistic knowledge representations and therefore various formal representational languages were created such as *schemata* (e.g. [124]), *semantic nets* [125], *frames* [126], *production systems* (e.g. [127]), and *scripts* [128]. Symbolic thought was assumed to be analogous to language processing in many ways, since both include sequential syntactical processing of words, as in the proposed representational models (e.g. [129]). Hence, the only form of situatedness in such systems is to have a mental model of the surrounding world, whereas embodiment did not matter at all [13].

The dawn of the computer age and progress within information theory (e.g. [120]) occurred simultaneously, resulting in another cornerstone of classical cognitive science and traditional AI, the computer metaphor for mind (cf. e.g. [11, 13]). Neisser, who can be viewed as the founding father of cognitive psychology, stated in his influential text *Cognitive Psychology* [130]:

> [t]he term 'cognition' refers to all the processes by which sensory information is transformed, reduced, elaborated, stored, recovered and used. It is concerned with these processes even when they operate in the absence of relevant stimulation, as in images and hallucinations. Such terms as sensation, perception, imagery, retention, recall, problem-solving, and thinking, among many others, refer to hypothetical stages or aspects of cognition (p. 4).

Taking such a view as the general framework for the study of mind, Neisser [130, 131] supposed there was a one-to-one mapping between the computations carried out by a digital computer and human thinking, since both the computer and the human mind "accept information, manipulate symbols, store items in 'memory' and retrieve them again, classify inputs, recognize patterns and so on" ([131], p. 5). Thus, cognitive psychology in the form of 'the computer metaphor for mind' became equivalent with human cognition. Neisser stressed that the actual task for cognitive psychologists was to understand the 'program' (i.e. software), and not the 'hardware'. In order to perform that task, he made the analogy between investigating human cognition and trying to understand how a computer was programmed [130]. This analogy was motivated by the belief that the human brain processed information in a similar way to the computer, which Pfeifer and Scheier [7] illustrate as follows:

> It became natural to think of human beings as information processing systems that received input from the environment (perception), process that information (thinking), and act upon the decision reached (behavior). This corresponds to the so-called sense-think-act cycle. Psychologists could now talk about "encoding", "search", "retrieval", "matching" and other information processing operations. The hope was to establish a strong theoretical and formal ground for conceptualizing human behavior that would replace behaviorist psychology. It seemed that anything humans do could be viewed in information processing terms: reading, remembering facts, recognizing objects, drawing logical conclusions, solving difficult problems, playing chess, conducting a conversation, and so fourth. Moreover, models couched in information processing terms were easy to formalize in terms of computer programs (p. 37).

As a result of equating cognition with the function of a computer, which is an artificial system that has the ability to process information, any machinery that could carry out a similar process independently of its hardware (brain tissue or mechanical device) was said to be, at least potentially intelligent. This view which is called *functionalism* and distinguishes between hardware and software levels and claims 'it is not the meat, it is the motion' that matters (cf. [132]). This means, cognition or intelligence could be analyzed at an algorithmical level or as computer processes without paying attention to the underlying structure of the device, on which the processes are performed. Consequently, the challenge for cognitive science was to discover the inner processes (or software) underlying intelligent behavior, and 'intelligence as computation' became the cognitivists' manifesto [7].

Accordingly, many computer programs were constructed in a functionalistic way that simulated higher human cognitive abilities, e.g., Newell and Simon's *General Problem Solver* [133] and more specific expert systems like MYCIN [134]. MYCIN was an expert system that proposed diagnoses of diseases caused by infections, with laboratory tests and symptoms as input, and MYCIN then presented some suitable antibiotics to cure the illness as output. An additional example of a program that used computational representations was SHRDLU [135], which mastered conversations about a small, simulated world of blocks. This program was able to respond to various issues about the block world and could also handle some manipulations with the blocks as outputs to stated questions.

In 1976, Newell and Simon presented the *Physical Symbol System Hypothesis* (PSSH), a kind of hallmark for the computational paradigm, claiming that thinking and cognition is symbol manipulation. The hypothesis states that symbol systems implemented in any device (e.g., brain, hardware, paper) have both the *necessary* and *sufficient* resources for general intelligence. By 'necessary' they meant that any system that does not have these properties cannot be intelligent, and 'sufficient' implied that a system having these characteristics had the potential to be intelligent [7]. Accordingly, the computer could be interpreted as evidence that 'mental' activities can occur in a physical device, without any need to speculate about an intervening 'spirit' or 'soul' in the system. Consequently, higher cognitive abilities were viewed as the formal rule-based, processing of internal symbols inside the brain analogous to a computer program, while body and environment were reduced to some kind of input and output devices.

According to Cisek [11], the computer metaphor for mind became successful because it offered convincing answers to major questions that confronted the field of psychology during the initial decades of the 20th century. He claims that the previous immaterial soul and mechanical body dualism was replaced with a mind/body dualism within the computational approach. Cisek points out that the explicit split between the immaterial mind and body resulted in two separate interfaces between the mind and the external reality, namely *perception* and *action*. However, humans are equipped with an organ, which has the ability to link these two processes together, allowing humans to have free will, rational thought and consciousness. Despite the fact that this kind of dualism was rejected, computationalism replaced the immaterial mind with a mechanical concept of cognition [11]. Consequently, the same structure of the design remained, laying the foundation for the *sense/perception-think/cognition-action* model of intelligent behavior. Accordingly, every psychological behavior was categorized either as perceptual, cognitive or motor control. The major focus for cognitive scientists was to investigate *how* cognition operates by converting perception into actions. However, even if the mind was initially considered distinct from the physical world, it could actually be studied scientifically by concepts of internal states. An attempt to solve the mind/body problem was functionalism, arguing that mental states correspond to functional states in the brain (or in the computer). However, this approach had to explain the qualitative difference between brain and mental phenomena [11].

Thus, computationalism offered the following explanations of the issues addressed above [11]. Firstly, the computer can be considered a model for how the mind works, namely by abstract symbol manipulation of internal representations. Secondly, it allowed a foundation for the discussion of non-dualistic internal states like memory, for instance. Thirdly, it offered the exciting metaphor of functionalism, which allowed mental states to be viewed as the software, running on the hardware. In addition, this functionalistic view provided an elegant answer about how to solve the gulf between biology and psychology, namely that cognitive phenomena are the software running on the (biological) hardware. Finally, computationalism provided a mathematical formalism in the languages of predicate logics, syntax, and information theory. All of these answers to the issues addressed earlier emerged within a short time span, and therefore it was not surprising that the computer metaphor became the viable and only model of how the mind actually works. However, not everyone was swayed by the 'power' of computationalism, and there were some which survived like "mammals under the dinosaurs" [11].

2.7 Criticisms of Computationalism and the Inception of Connectionism

In the late 1970 s several lines of criticism emerged against the 'narrow' computational approach. Dreyfus [4, 5] and Searle [136] made the most significant attacks against the strong faith in computationalism. The common theme in their attacks was the lack of connections between the external world and the internal representations. Dreyfus [4, 5], in his book *What Computers Can't do: a Critique of Artificial Reasons*, argued that the quandary for the traditional approach is that the knowledge in a computer is represented from the 'outside'. He stated [5]:

> Even if it represents all human knowledge in its stereotypes, including all possible human situations, it represents it from the outside like a Martian or a god. It isn't situated in any of them, and it may be impossible to program it to behave as if it were (p. 52).

This means, someone had designed and declared the 'knowledge', since it is not present or situated in the program itself. The only relation of the 'knowledge' to the external environment is through the creator of the program, who decided *how* to conceptualize elements in the surrounding world. The designer also made the selection *what* is relevant or not to be represented. The program did not have a direct link or mapping between the external world and the internal representations of it. The mapping went via the designer and the direct link was an 'illusion' by the observer, who shared the linking between the external world and the internal representations with the designer. For this reason the system itself lacked a common sense understanding, because it only dealt with predetermined facts. As a consequence, the program's creator/observer in some sense was its only context [12, 13].

Furthermore, Dreyfus [4, 5] maintained the traditional AI-programs only mastered *micro-worlds*, slices of limited problem areas and/or isolated parts of human cognitive abilities. Examples of micro-worlds are game playing computers, language 'understanding' using a form of scripts, and expert systems like MYCIN. The common factor is all of them could not manage tasks in a natural environment. Dreyfus strongly attacked the lack of *situatedness* in these formal representations [4, 5]. The motivation for his criticism was that the programs did not have the necessary background information, independent of the amount of explicit knowledge and rules they enclosed, which was the consequence of the lack of 'first hand semantics' in traditional AI programs [12]. According to Dreyfus [4, 5], it is not sufficient or possible to represent 'everything'. Instead he argued that we had to go beyond the formal representations and take the body and the surrounding world into account "*since intelligence must be situated it cannot be separated from the rest of the human life*" (p. 62). This 'rest of human life' is the body's influence on cognition, cultural factors, and common sense knowledge, which may be impossible to define explicitly. Therefore it would not be possible to represent intelligence within a traditional computer program. According to Ziemke [12], Dreyfus might have been the first person to use the concept of 'situatedness' within the area of AI, and Dreyfus [5] motivated his argument that situatedness and embodiment might be the core properties for intelligence as follows:

> Human beings … they are, as Heidegger puts it, always in a situation, which they constantly revise … We can see that human beings are gradually trained into their cultural situation on the basis of their *embodied* precultural situation in a way no programmer using KRL [Knowledge Representing Language] is trying to capture. But for this very reason a program is not always-already-in-a-situation … it seems that our sense of our situation is determined by our changing moods, by our current concerns and projects, by our long-range self-interpretation and probably also by our *sensory-motor skills* for coping with objects and people skills we develop *by practice without ever having to represent to ourselves*, our body as an object, our culture as a set of beliefs, and our propensities as situation $a \rightarrow b$ action rules. All these uniquely human capacities provide a "richness" or a "thickness" to our way of "*being-in-the-world and thus seem to play an essential role in situatedness, which in turn underlies all intelligent behavior*" (pp. 52–53, emphases added).

This means, Dreyfus [4, 5] argued that intelligence requires a 'background of common sense' which humans are equipped with by virtue of being *embodied*, and *situated* in their physical, social, and cultural world. However, computers are not embodied or situated in that sense, and therefore computers do lack 'practical intelligence'. Consequently, Dreyfus claimed that computers can be considered 'existentially' stupid, despite the fact that they can successfully deal with formal languages and logical relations [4, 5].

Dreyfus particularly emphasized the role of embodiment in intelligent behavior, arguing that in order to make embodiment a tentative approach in cognitive science and AI, there was a need to demonstrate how it would be possible to perform a task like waving a hand in the air without appealing to any principles of physics and/or geometry. He proposed an alternative, embodied explanation of intelligence, in which the body itself plays a significant role by means of three functions that might be lacking in (digital) computer programs [4, 5]. Firstly, he mentioned the 'inner horizon',[12] which can be illustrated as a kind of partial unspecified anticipation of perception. For instance, when perceiving a certain object, the surrounding context, previous experiences, and certain anticipations affect the possible interpretations of the object. Hence, the possible interpretations are neither made at random nor are they predetermined. Secondly, the overall character of this 'inner horizon' decides the meaning of the detailed elements it integrates and becomes determined by them. Thirdly, the body's capacity to transfer this perceived anticipation to a motoric action, and as stated by Dreyfus [5], "all these are included in the general human ability to acquire bodily skills. Thanks to this fundamental ability an embodied agent can dwell in the world in such a way as to avoid the infinite task of formalizing everything" (p. 255). Consequently, representations may not be necessary, since it appears probable that humans can, for instance, learn to swim by developing the necessary movements through practice, without any need to represent the bodily (and muscular) movements in a kind of formalistic structure. Moreover, he noted [5] that studies in developmental psychology have demonstrated that "learning of specific details takes place on a background of shared practices which seem to be picked up in everyday interactions not as facts and beliefs but as bodily skills for coping with the world" (p. 47). In sum, these sensory motor skills appear to underlie all the "higher" mental functions, and these kinds of pattern recognitions are not achievable for the digital computer that obviously lacks a body, and therefore cannot utilize these functions [5]. Dreyfus finally addressed the questions if it would be possible to make an *artificial embodied agent* and if it is possible to build such a robot by using digital computers. Dreyfus believed that, hypothetically, it would be possible to construct such an artificial embodied agent, but it would require that the agent be equipped with sensorimotor mechanisms that resembled the ones humans and other living organisms have [4, 5].

Searle's [136] much debated *Chinese Room Argument* addressed the lack of understanding in the computer program itself, and Searle made the distinction between 'strong AI' and 'weak AI'. He described 'strong AI' as the view that a computer program really could understand and think, i.e. has a real mind, while 'weak AI' is the view that a computer program could be used as a tool for studying intelligence. A brief description of his thought experiment, the Chinese Room Argument, follows. A person is located into a room and given a narrative in Chinese; but the person does not understand a word of Chinese. There is also a rule book in the room that explains how to link Chinese signs to each other. The person in the room receives from the outside questions written in Chinese that he/she must reply to in Chinese. In order

[12]The term was coined by Husserl.

to manage this task, the person uses the rules and the given set of Chinese signs, and as a result, he/she sends out correct answers (in Chinese), even though the person in fact knows no word of Chinese. To an outside observer it seems as if the person in the room actually understands Chinese. According to Searle, the person in the room is behaving exactly the same way as a running computer program, manipulating symbols (Chinese signs) by following some rules [136]. The same happens in traditional AI programs, they behave as if they were intelligent, but something important is missing. The program itself has no understanding of what it is doing; there is a lack of intentionality, since the person or program never interprets what the symbols stand for. The person does not understand what the story in Chinese is about, and neither does a computer system running a program, that is, understanding what it is doing in the sense of others' interpretation of the program's operation. Thus, Searle reached the conclusion that there is no relation between the internal representations (symbols) and the external represented objects in the world within traditional AI systems [136]. The interpretation of the symbols is made by the designer (or the observer) but not by the system itself. This problem is nowadays called the "symbol-grounding problem" [137]. However, as pointed out by Ziemke [12], some misinterpretations of Searle's conclusion exists [138]. He did not actually claim that attempts to build intelligent machines were doomed to fail, rather he argued that the mistake conducted by contemporary AI was that it dealt with computer programs but "has nothing to tell us about machines" ([136] i.e. embodied systems, in today's terms). This means, Searle actually accused AI of being dualistic, since disembodied computer programs were characterized as intelligent. As an alternative, Searle argued that AI systems should be equipped with some of the "causal powers" of living organisms, such as perception, and action, allowing these systems to link their internal structures to their 'own' real world [12, 138].

Another challenge to cognitive science was to extend the functionalistic view by taking the neurological aspects of cognition into account, and in the 1980 s a new form of modeling cognitive phenomena emerged, namely *connectionism* (e.g. [139]). However, connectionism was not a totally new approach; rather there was a re-emergence of neural network research. Already in 1943, McCulloch and Pitts demonstrated that networks of neuron-like units were able to compute complex logical functions, and in 1958, Rosenblatt presented his seminal paper on the *Perceptron*. Despite having all the fundamental ideas, neural network research did not progress well at that time [1, 7].

Connectionists use *artificial neural networks* (ANN), which are, to some degree, able to imitate and resemble the brain's distributed functions at a general level. Accordingly, connectionism regards cognition as brain activity, consisting of a huge collection of interconnected simple units (neurons), which process information in parallel, contrary to symbolic and formalistic models in which the processing is discrete. Broadly speaking, the two main characteristics of neural networks are their ability to learn and their emergent properties (for a more detailed description see e.g. [7, 12, 139]). Each individual neuron in a network receives 'activity' from their closest neighbors, and every neural connection has a weight, which can be positive (exhibitory) or negative (inhibitory). The forwarded 'activity' is determined by the product of the numerical weight and the strength of the signal from the sending neuron. The strengths of the connections between the neurons can be altered by adding new input to the network and applying some learning techniques. Consequently, neural networks are capable of making mappings from input to output by themselves, as a kind of learning process. While formalistic symbolic systems were only able to simulate and handle well-defined tasks, neural networks are flexible and can manage fuzzy input. Therefore, they are useable for assignments that are not formalizable, e.g. pattern-recognition tasks. Hence, neural networks are able to carry out tasks that the designer has not directly programmed into them. This means, a neural network functions as a self-organizing system, similar to the brain, and through this massive parallel processing the ability of cognition emerges. Accordingly, cognitive processes should not be regarded as symbol manipulation, but as activity pattern [7, 49].

Broadly speaking, the same major criticisms that were directed at representationalism and functionalism have also been turned against connectionism (cf. [12, 13]). For instance, artificial neural networks do not solve the 'symbol grounding problem' themselves, since most networks begin from the designer's specification of the task. This means, networks do represent properties in the world, although at another level, but it is still the designer that decides from the 'outside' which properties should be represented. Moreover, the biological plausibility of neural networks is very limited, and therefore do not serve as realistic models of biological neurons, given the trade-off between biological authenticity and algorithmic simplicity. Consequently, there is a tentative risk in making this simplification, since it is plausible one might miss the very characteristics of intelligence in natural organisms [7]. Another criticism was the request for evolutionary explanations, since it has been argued that only simulating human intelligence is not satisfying, instead we have to ask how and why these abilities come to be there [99].

In conclusion, the role of *embodiment*, *situatedness* and *environment* was still neglected within both traditional cognitive science (computationalism and connectionism) (see [49]). However, as Pfeifer and Scheier point out, neural networks are viewed as information processors, but if they become embedded in physical robots they might, hypothetically, transform robots into *intelligent autonomous agents* [7].

2.8 In Summary

From the brief historical overview, it is clear that the idea of mind or cognition being embodied is by no means new. At different times and for different reasons, theorists have sought to understand the mind from alternative perspectives. Thus, the idea of the mind as a kind of 'rational calculating device' that was earlier proposed by Plato and Descartes, was realized through the use of the digital computer as the metaphor for mind. However, for several reasons the rational and formalized perspective became the dominating approach in cognitive science and symbolic AI, and consequently the role of the body and the environment was disregarded in efforts to find the key mechanisms for intelligence. Clancey [2] mentions that Lakoff offered an appropriate review of the computational paradigm, which is as follows [140]

> The traditional view is a philosophical one. It has come out of two thousand years of philosophizing about the nature of reason. It is still widely believed despite overwhelming empirical evidence against it … We have all been educated to think in those terms … Modern attempts to make it work assume that rational thought consists of the manipulation of abstract symbols and that these symbols get their meaning via a correspondence with the world, objectively constructed, that is independent of the understanding of any organism … Though such views are by no means shared by all cognitive scientists, they are nevertheless widespread, and in fact so common that many of them are often assumed to be true without question or comment (Lakoff, 1987, cited in [2] pp. 51–52).

Dreyfus also emphasized that the computer in fact was the product of over 2,500 years of traditional thinking of Plato's legacy [4, 5]. Additionally, Cisek noted that the so-called cognitive revolution was just "old wine in new bottles" in a philosophical sense [11]. However, the emerging viewpoint of embodied cognition claims that our cognitive processes are deeply rooted within our brain and body's interactions with the surrounding world, which can be viewed as a Copernican revolution against computationalism. This is discussed in detail in the following chapters.

References

1. Bechtel, W., Abrahamsen, A., Graham, G.: The life of cognitive science. In: Bechtel, W., Graham, G. (eds.) A Companion to Cognitive Science, pp. 2–104. Blackwell Publisher, Malden, MA (1998)
2. Clancey, W.J.: Situated Cognition: On Human Knowledge and Computer Representations. Cambridge University Press, New York (1997)
3. Clark, A.: Mindware: An Introduction to the Philosophy of Cognitive Science. Oxford University Press, New York (2001)
4. Dreyfus, H.L.: What Computers Can't Do: A Critique of Artificial Reason. (This book is contained in the extended MIT Press edition (Dreyfus, 1992) to which all page numbers refer). Harper & Row, New York (1972)
5. Dreyfus, H.L.: What Computers Still Can't Do: A Critique of Artificial Reason. MIT press, Cambridge, MA (1992)
6. Gardner, H.: The Mind's New Science: A History of the Cognitive Revolution. Basic Books, New York (1987)
7. Pfeifer, R., Scheier, C.: Understanding Intelligence. MIT Press, Cambridge, MA (1999)
8. Freeman, W.J., Núñez, R.: Restoring to cognition the forgotten primacy of action, intention and emotion. In: Reclaiming Cognition the Primacy of Action, Intention and Emotion, pp. ix–xix. Imprint Academic, Bowling Green, OH (1999)
9. Ritvo, H.: The animal connection. In: Sheehan, J.J., Sosna, M. (eds.) The Boundaries of Humanity: Humans, Animals and Machines, pp. 68–84. University of California Press, Berkeley (1991)
10. Sparks, J.: The Discovery of Animal Behaviour. Collins, London (1982)
11. Cisek, P.: Beyond the computer metaphor: Behaviour as interaction. J. Conscious. Stud. **6**(11–12), 125–142 (1999)
12. Ziemke, T.: Situated Neuro-Robotics and Interactive Emergence. Ph.D. thesis, Doctoral dissertation, Departament of Computer Science, University of Sheffield, UK (2000)

13. Ziemke, T.: The construction of 'reality' in the robot: Constructivist perspectives on situated artificial intelligence and adaptive robotics. Found. Sci. **6**(1–3), 163–233 (2001)
14. Darwin, C.: On the Origin of Species. John Murray, London (1859)
15. Cosmides, L., Tooby, S., Turner, J.H., Velichkovsky, B.M.: Looking back: historical context of present practice—biology and psychology. In: Weingart, P., Mitchell, S.D., J, R.P. Maasen, S. (eds.) Human by Nature-Between Biology and the Social Sciences, pp. 52–64. Lawrence Erlbaum, Mahwah, NJ (1997)
16. McFarland, D.: Animal Behaviour: Psychobiology. Ethology and Evolution. Longman, Harlow (1993)
17. Gould, J.L., Gould, C.G.: The Animal Mind. Scientific American Library, New York (1994)
18. Darwin, C.: The Descent of Man. John Murray, London (1859)
19. Sheets-Johnstone, M.: The Primacy of Movement. John Benjamins Publishing Company, Amsterdam (1999)
20. Ekman, P.: Introduction to the third edition of [Darwin's] Expression. In: Expression of the Emotions in Man and Animals, pp. 7–32. Harper Collins, London (1998)
21. Darwin, C.: The expression of the emotions in man and animals. In: Ekman, P. (ed.) The Expression of the Emotions in Man and Animals. Harper Collins, London (1998)
22. Ingold, T.: Culture and human nature: an obituary notice. In: Paper Presented at the Ninth International Conference on Hunting and Gathering Societies CHAGS (2002)
23. Allen, C., Bekoff, M.: Species of Mind: The Philosophy and Biology of Cognitive Ethology. MIT Press, Cambridge, MA (1999)
24. Manning, A., Dawkins, M.S.: An Introduction to Animal Behaviour. Cambridge University Press, Cambridge (1998)
25. Lloyd, D.E.: Simple Minds. MIT Press, Cambridge, MA (1989)
26. Knapp, M., Hall, J.: Nonverbal Communication in Human Interaction, 4th edn. Harcourt Brace College Publication, Fort Worth, Texas (1997)
27. Darwin, C.: The Power of Movement in Plants. John Murray, London (1880)
28. Sachs, J.: Vorlesungen über Pflanzen-Physiologie. W. Engelmann, Leipzig (1882)
29. Sherrington, C.S.: The Integrative Action of the Nervous System. C Scribners Sons, New York (1906)
30. Fraenkel, G., Gunn, D.: The Orientation of Animals: Kineses. Taxes and Compass Reactions. Clarendon Press, Oxford (1940)
31. Sharkey, N.E., Ziemke, T.: Mechanistic versus phenomenal embodiment: Can robot embodiment lead to strong AI? Cogn. Syst. Res. **2**(4), 251–262 (2001)
32. Bechtel, W., Zawidzki, T.: Selective biographies of major contributors to cognitive science. In: Bechtel, W., Graham, G. (eds.) A Companion to Cognitive Science, pp. 750–776. Blackwell Publisher, Malden, MA (1998)
33. Shaughnessy, J.J., Zechmeister, E.B.: Research Methods in Psychology. McGraw Hill, New York (1997)
34. William, J.: The Principles of Psychology. Holt, New York (1890)
35. Dewey, J.: The reflex arc concept in psychology. Psychol. Rev. **3**(4), 357–370 (1896)
36. Skinner, B.F.: The Behavior of Organisms: An Experimental Analysis. Appleton-Century-Crofts, New York (1938)
37. Chrisley, R., Ziemke, T.: Embodiment. In: Nadel, L. (ed.) Encyclopedia of Cognitive Science: Vol. 1, Academic achievements-Environmental Psychology, pp. 1102–1108. MacMillian Publishers, London (2003)
38. Watson, J.B.: Psychology as the behaviorist views it. Psychol. Rev. **20**(2), 158–177 (1913)
39. Watson, J.B.: Behaviorism. W W Norton & Co, New York (1930)
40. Skinner, B.F.: Science and Human Behavior. MacMillan, New York (1953)
41. Alcock, J.: Animal Behavior: An Evolutionary Approach. Sinauer Associates, Sunderland, MA (1993)
42. Burghardt G, M.: Editors comments on papers 13 through 16. In: Burghardt G, M. (ed.) Foundations of Comparative Ethology, pp. 218–221. Van Nostrand Reinhold Company, New York (1985)

43. Lorenz, K.: Foreword. In: Burghardt G, M. (ed.) Foundations of Comparative Ethology, pp. xiii–xiv. Van Nostrand Reinhold Company, New York (1985)
44. Walther, F.R.: Konrad Z. Lorenz. Proc. Am. Philos. Soc. **143**(3), 459–469 (1999)
45. Bekoff, M.: Minding Animals. Oxford University Press, New York (2002)
46. Bekoff, M., Allen, C., Burghardt, G.M.: The Cognitive Animal: Empirical and Theoretical Perspectives on Animal Cognition. MIT Press, Cambridge, MA (2002)
47. Uexküll, J.v.: A stroll through the worlds of animals and men: a picture book of invisible worlds (Originally published in German 1934). Semiotica **89**(4), 319–391 (1957)
48. Brooks, R.A.: Intelligence without representation. In: Proceedings of the Twelfth International Joint Conference on Artificial Intelligence IJCAI'91, vol. 1, pp. 569–595. Morgan Kaufmann, San Francisco, CA (1991)
49. Clark, A.: Being There: Putting Brain, Body, and World together Again. MIT Press, Cambridge, MA (1997)
50. Emmeche, C.: Does a robot have an Umwelt? Reflections on the qualitative biosemiotics of Jakob von Uexküll. Semiotica **134**(1/4), 653–694 (2001)
51. Uexküll, J.v.: Environment (Umwelt) and inner world of animals (Appeared as a partial translation of the original work from 1909). In: M. Burghardt G (ed.) Foundations of Comparative Ethology, pp. 222–245. Van Nostrand Reinhold Company, New York (1985)
52. Uexküll, J.v.: Theoretische Biologie. Verlag von Julius Springer, Berlin (1928)
53. Tinbergen, N.: The Study of Instinct. Oxford University Press, New York (1951)
54. Tinbergen, N., Perdeck, A.C.: On the stimulus situation releasing the begging response in the newly hatched herring gull chick. Behaviour pp. 1–39 (1950)
55. Tinbergen, N.: Curious Naturalists. Doubleday, Garden City, NY (1958)
56. Segerstråle, U.C., Molnár, P.: Nonverbal communication: where nature meets culture. In: Segerstråle, U., Molnár, P. (eds.) Nonverbal Communication: Crossing the Boundary between Culture and Nature, pp. 1–21. Lawrence Erlbaum, Mahwah, NJ (1997)
57. Eibl-Eibesfeldt, I.: Human Ethology. Aldine de Gruyter, New York (1989)
58. Rogoff, B.: The Cultural Nature of Human Development. Oxford University Press, New York (2003)
59. Köhler, W.: The Mentality of Apes (2nd rev.). Routledge & Kegan Paul, London (1925)
60. Gibson, J.J.: The Senses Considered as Perceptual Systems. Houghton Mifflin, Boston (1966)
61. Gibson, J.J.: The Ecological Approach to Visual Perception. Houghton Mifflin, Boston (1979)
62. Mace, W.M., James J.: Gibson's strategy for perceiving: Ask not what's inside your head, but what your head's inside of. In: Bransford, J., Shaw, R.E. (eds.) Perceiving, Acting, and Knowing—Toward an Ecological Psychology, pp. 43–65. Lawrence Erlbaum Associates, Hillsdale, NJ (1977)
63. Priest, S.: Merleau-Ponty. Routledge, London (1998)
64. Merleau-Ponty, M.: The Structure of Behaviour (Originally Published in French 1942). Beacon Press, Boston (1963)
65. Loren, L.A., Dietrich, E.: Merleau-Ponty, embodied cognition, and the problem of intentionality. Cybernetics and Systems **28**(5), 345–358 (1997)
66. Dreyfus, H.L.: Being-in-the-World: A commentary on Heidegger's Being and Time. Division I. MIT Press, Cambridge (1991)
67. Merleau-Ponty, M.: Phenomenology of Perception (Originally published in French 1945). Routledge, London (1962)
68. Mingers, J.: Embodying information systems: the contribution of phenomenology. Inf. Organ. **11**(2), 103–128 (2001)
69. Varela, F.J., Thompson, E., Rosch, E.: The Embodied Mind: Cognitive Science and Human Experience. MIT Press, Cambridge, MA (1991)
70. Dreyfus, H.L., Dreyfus, S.E.: The challenge of Merleau-Ponty's phenomenology of embodiment for cognitive science. In: Haber, W.G, H.F. (eds.) Perspectives on Embodiment: The Intersections of Nature and Culture, pp. 103–120. Routledge, New York (1999)
71. Dreyfus, H.L.: Intelligence without representation: Merleau-Ponty's critique of mental representation the relevance of phenomenology to scientific explanation. Phenomenology and the Cognitive Sciences **1**(4), 367–383 (2002)

72. Merleau-Ponty, M.: The Visible and the Invisible (Originally published in French 1964). Northwestern University Press, Evanston (1969)
73. Neuman, Y.: On Turing's carnal error: some guidelines for a contextual inquiry into the embodied mind. Systems Research and Behavioral Science **18**(6), 557–564 (2001)
74. Lakoff, G., Núñez, R.E.: Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being. Basic books, New York (2000)
75. Piaget, J.: The Origins of Intelligence in the Children (Originally published in French 1936). International University Press, New York (1952)
76. Piaget, J.: The Construction of Reality in the Child (Originally published in French 1937). Basic Books, New York (1954)
77. Boden, M.: Piaget. Fontana Press, London (1994)
78. Fischer, K., Kaplan, U.: Piaget, Jean. In: L. Nadel (ed.) Encyclopedia of Cognitive Science: Vol. 3, Mental models-Mental imagery, pp. 679–682. MacMillan Publishers, London (2003)
79. Sinha, C., De Lopez, K.J.: Language, culture, and the embodiment of spatial cognition. Cognitive Linguistics **11**(1/2), 17–42 (2000)
80. Wadsworth, B.J.: Piaget's Theory of Cognitive and Affective Development: Foundations of Constructivism, 5th edn. Longman Publishing, New York (1996)
81. Glasserfeld, E.v.: Radical Constructivism: A Way of Knowing and Learning. The Palmer Press, London (1995)
82. Gredler, M.E.: Learning and Instruction: Theory into Practice. MacMillan, New York (1992)
83. Miller, P.H.: Theories of Developmental Psychology. W H Freeman Henry Holt & Co, New York (1993)
84. Vauclair, J., Perret, P.: The cognitive revolution in Europe: taking the developmental perspective seriously. Trends in Cognitive Sciences **7**(7), 284–285 (2003)
85. Cole, M., Wertsch, J.V.: Beyond the individual-social antinomy in discussions of Piaget and Vygotsky. Hum. Dev. **39**(5), 250–256 (1996)
86. Kozulin, A.: Vygotsky in context. In: Vygotsky, L.S. (ed.) Thought and Language, pp. xi–lvi. MIT Press, Cambridge, MA (1986)
87. Vygotsky, L.S.: Consciousness as a problem in the psychology of behavior (Originally published in Russian 1925). Journal of Russian and East European Psychology **17**(4), 3–35 (1979)
88. Vygotsky, L.S.: Mind in Society. The Development of Higher Psychological Processes (Originally published in Russian 1934). Harvard University Press, Cambridge, MA (1978)
89. Vygotsky, L.S.: The development of higher psychological Functions (Original work published in Russian 1929). J. Russ. East Eur. Psychol. **15**(3), 60–73 (1977)
90. Wertsch, J.V.: Vygotsky and the Social Formation of Mind. Harvard University Press, Cambridge, MA (1985)
91. Vygotsky, L.S.: Thought and Language (Originally Published in Russian 1934). MIT Press, Cambridge, MA (1986)
92. Lindblom, J., Ziemke, T.: Social situatedness of natural and artificial intelligence: Vygotsky and beyond. Adaptive Behavior **11**(2), 79–96 (2003)
93. Davydov, V.V., Radzikhovskii, L.A.: Vygotsky's theory and the activity-oriented approach to psychology. In: Wertsch, J.V. (ed.) Culture, Communication, and Cognition: Vygotskian Perspectives, pp. 35–65. Cambridge University Press, New York (1985)
94. Johnson, M.: The Body in the Mind: The Bodily Basis of Meaning, Reason and Imagination. University of Chicago Press, Chicago (1987)
95. Field, R.: John Dewey (2001)
96. Marsh, L.: Dewey: the first ghost-buster? Trends in Cognitive Science **10**(6), 242–243 (2006)
97. Dewey, J.: Experience and Nature (Originally Published in 1925), vol. 1. Courier Dover Publications, New York (1958)
98. Rockwell, W.T.: Neither Brain nor Ghost: A Nondualist Alternative to the Mind-brain Identity Theory. MIT Press, Cambridge, MA (2005)
99. Hendriks-Jansen, H.: Catching Ourselves in the Act: Situated Activity, Interactive Emergence, Evolution, and Human Thought. MIT Press, Cambridge, MA (1996)

100. Bartlett, F.C.: Remembering: A Study in Experimental and Social Psychology. Cambridge University Press, Cambridge (1932)
101. Roediger, H.L.: Bartlett, Frederic Charles. In: L. Nadel (ed.) Encyclopedia of Cognitive Science: Vol. 1, Academic achievements-Environmental psychology, pp. 319–322. MacMillian Publishers, London (2003)
102. Saito, A.: Social origins of cognition: Bartlett, evolutionary perspective and embodied mind approach. Journal for the Theory of Social Behaviour **26**(4), 399–421 (1996)
103. Bartlett, F.C.: Psychology and Primitive Culture. Cambridge University Press, Cambridge (1923)
104. Cronk, G.: Mead, George Herbert (2005)
105. Lewis, M.: Social cognition and the self. In: Rochat, P. (ed.) Early Social Cognition: Understanding Others in the First Months of Life, pp. 81–98. Lawrence Erlbaum, Mahwah, NJ (1999)
106. Mead, G.H.: Mind, Self, and Society. University of Chicago Press, Chicago (1934)
107. Gillespie, A.: G H Mead: Theorist of the social act. Journal for the Theory of Social Behaviour **35**(1), 19–39 (2005)
108. Varela, C.R.: Harré and Merleau-Ponty: beyond the absent moving body in embodied social theory. Journal for the Theory of Social Behaviour **24**(2), 167–185 (1994)
109. Farnell, B.: Moving bodies, acting selves. Annu. Rev. Anthropol. **28**, 341–373 (1999)
110. Breland, K., Breland, M.: The misbehavior of organisms. Am. Psychol. **16**(11), 661–664 (1961)
111. Garcia, J., Koelling, R.A.: Relation of cue to consequence in avoidance learning. Psychon. Sci. **4**(1), 123–124 (1966)
112. Harlow, H.F.: The nature of love. Am. Psychol. **13**(12), 673 (1958)
113. Harlow, H.F.: Love in infant monkeys. Sci. Am. **200**(6), 68–74 (1959)
114. Masson, J.M., McCarthy, S.: When Elephants Weep: The Emotional Lives of Animals. Dell Publishing, New York (1995)
115. Sharkey, N.E., Ziemke, T.: A consideration of the biological and psychological foundations of autonomous robotics. Connection Sci. **10**(3–4), 361–391 (1998)
116. Turing, A.M.: Computing machinery and intelligence. Mind pp. 433–460 (1950)
117. Wilson, E.: 'Loving the computer'—cognition, embodiment and the influencing machine. In: Stam, H.J. (ed.) The Body and Psychology, pp. 71–93. Sage Publications, London (1998)
118. Leiber, J.: Helen Keller as cognitive scientist. Philos. Psychol. **9**(4), 419–440 (1996)
119. Lindblom, J., Ziemke, T.: Social situatedness: Vygotsky and beyond. In: Prince, C.G., Demiris, Y., Marom, Y, Kozima, H., Balkenius, C. (eds.) Proceedings of the Second International Workshop on Epigenetic Robotics: Modelling Cognitive Development in Robotic Systems, pp. 71–78. Lund University Cognitive Studies, LUCS 94, Sweden, Lund (2006)
120. Shannon, C.E.: A Mathematical Theory of Communication. The University of Illinois Press, Chicago (1948)
121. Chomsky, N.: A review of BF Skinner's Verbal Behavior. Language **35**(1), 26–58 (1959)
122. Skinner, B.: Verbal Behavior. Prentice Hall, Englewoods Cliffs, NJ (1957)
123. Craik, K.J.W.: The Nature of Explanation. Cambridge University Press, Cambridge (1943)
124. Posner, M.I.: Cognition: An Introduction. Scott, Foresman and Company, Glenview, Ill (1973)
125. Collins, A.M., Quillian, M.R.: Retrieval time from semantic memory. J. Verbal Learn. Verbal Behav. **8**(2), 240–247 (1969)
126. Minsky, M.: A framework for representing knowledge. In: Winston, P.H. (ed.) The Psychology of Computer Vision, pp. 211–277. McGraw-Hill, New York (1975)
127. Anderson, J.R.: The Architecture of Cognition. Harvard University Press, Cambridge, MA (1983)
128. Schank, R.C., Abelson, R.P.: Scripts, Plans, Goals and Understanding: An Inquiry into Human Knowledge Structures. Lawrence Erlbaum, Hillsdale, NJ (1977)
129. Fodor, J.A., Pylyshyn, Z.W.: Connectionism and cognitive architecture: a critical analysis. Cognition **28**(1), 3–71 (1988)
130. Neisser, U.: Cognitive Psychology. Appleton-Century-Crofts, New York (1967)

131. Neisser, U.: Cognition and Reality: Principles and Implications of Cognitive Psychology. W H Freeman, San Fransisco, CA (1976)
132. Putnam, H.: Minds and machines. In: Hook, S. (ed.) Dimensions of Mind, pp. 57–80. New York University Press, New York (1960)
133. Newell, A., Simon, H.A.: GPS, a program that simulates human thought. In: Billing, H. (ed.) Lernade Automaten, pp. 109–124. R. Oldenburg, Munich (1961)
134. Shortliffe, E.H.: MYCIN: Computer-Based Medical Consultations. Elsevier, New York (1976)
135. Winograd, T.: Understanding natural language. Cogn. Psychol. **3**(1), 1–191 (1972)
136. Searle, J.R.: Minds, brains, and programs. Behav. Brain Sci. **3**(3), 417–424 (1980)
137. Harnad, S.: The symbol grounding problem. Physica D **42**(1), 335–346 (1990)
138. Searle, J.R.: The Chinese room argument. In: Nadel, L. (ed.) Encyclopedia of Cognitive Science: Vol. 1, Academic achievemnts-Environmental psychology, pp. 496–500. MacMillian Publishers, London (2003)
139. McClelland, J.L., Rumelhart, D.E.: Parallel Distributed Processing: Explorations in the Microstructures of Cognition (Volume 1 and 2). MIT Press, Cambridge, MA (1986)
140. Lakoff, G.: Women, Fire and Dangerous Things: What Categories Tell Us about the Human Mind. University of Chicago Press, Chicago (1987)

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