A DISCUSSION OF JAMES J. GIBSON'S THEORY OF VISUAL PERCEPTION IN THE CONTEXT OF EMBODIED COGNITION

JAMES J. GIBSON'IN GÖRSEL ALGI KURAMININ BEDENLENMİŞ BİLİŞ KAVRAMI BAĞLAMINDA BİR TARTIŞMASI

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Abstract

This paper aims to discuss James J. Gibson's theory of visual perception in the context of embodied cognition. First, Gibson's theory is discussed in the context of simple vs. radical embodiment distinction proposed by Clark (348). Then, it is discussed in the context of conceptualization, replacement and constitution categorization proposed by Shapiro (Embodied Cognition: New… 4). In order to highlight similarities and the differences, Gibson's theory is also compared with other studies advocating the embodiment such as Thelen et al.'s (1) dynamical approach to cognitive development, O'Regan and Noë's (A sensory motor account… 1; What is it like… 1) sensorimotor approach to perception and Varela et al.'s (1) enactive approach to cognition. The paper ends with a summary of the meaning of the embodiment in Gibson's theory.

Öz

Bu makalede, James J. Gibson'ın görsel algı kuramının bedenlenmiş biliş kavramı bağlamında bir tartışması sunulmaktadır. Gibson'ın görsel algı kuramı, ilk olarak, Clark (348) tarafından öne sürülen basit bedenleme ve radikal bedenlenme ayrımı çerçevesinde tartışılmıştır. Daha sonra, Gibson'ın kuramı, Sharpiro tarafından önerilen kavramlaştırma, değiştirme ve oluşturma kategorileri bağlamında tartışılmıştır (Embodied Cognition: New… 4). Ardından Gibson'ın kuramı, bilişsel gelişime dinamik yaklaşım (Thelen ve diğerleri 1), algıya duyusal motor yaklaşım (O'Regan ve Noë, “A sensory motor account…” 1; O'Regan ve Noë, “What is it like…” 1) ve bilişe enaktif yaklaşım (Varela ve diğerleri 1) gibi bedenlenmeyi savunan diğer çalışmalar ile karşılaştırılmış; Gibson'ın kuramı ve bu çalışmalar arasındaki benzerlikler ve farklılıklar vurgulanmıştır. Makalenin sonunda bedenlenmenin Gibson'ın kuramındaki anlamına yönelik bir özet sunulmuştur.

Introduction

Embodied cognition emphasizes the way cognition is shaped by the body and its sensory motor interactions with the world. Rather than seeing cognition as the achievement of the brain alone, it argues that cognition can be best understood as resulting from the mutual interactions between the brain, the body and the environment. Even though the emphasis on the body's and the environment's roles in cognitive processing is at the core of embodied cognition, the term embodied cognition cannot be attached to a single, unified, conception of mind and involves many different research projects (Shapiro, *Embodied Cognition: New…* 51).

Embodied cognition has emerged as a reaction to traditional cognitive science, according to which cognition is a process of symbol manipulation. The traditional view argues that the sense organs register and transform the stimulation from the environment into amodal symbols and the mind operates on these symbols, manipulates them according to the syntactic rules, creating additional symbols. Cognition is computation and the brain is the place where it occurs. It starts when the nervous system receives inputs and ends when it calculates the output. Cognition is disembodied in the sense that the body does not play any significant role in cognitive processing other than registering input and performing the output. It is disembedded in the sense that the environment is considered only as a source of input.

This traditional view of cognition faces various challenges. Shapiro identifies two of these challenges as the main reasons that motivated researchers to develop alternative approaches to cognition ("The Embodied Cognition…" 339). The first challenge concerns the mental content of symbols. How do symbols in the head acquire their meaning? And the second challenge comes from the artificial intelligence and robotics research. It is the frustration over the limited success of the sense-plan-act paradigm of the traditional approach, especially when it comes to build a robot that can successfully navigate in a cluttered, dynamic and unpredictable environment. The embodied cognition tries to overcome these difficulties by relying on the interactions between the brain, the body and the environment.

Even though the embodied cognition is considered as a reaction to traditional cognitive science, it involves different research projects that criticize different aspects of the traditional view. Some research projects still hold the explanatory tools of traditional view such as mental representations and processes operating on those representations. However, they argue that the body and the environment play a significant role in formation of representations. Some research projects, still advocating the computational view of cognition, reject the traditional claim that the constituents of cognitive processes are completely within the skull. They argue that the constituents of cognitive processes can extend beyond the brain into the body and the environment. Yet another group of projects rejects the traditional view completely, arguing that representations and processes operating on those representations are not the right tools for explaining cognition and should be abandoned in favor of new tools and methods. Such an alternative is the tools of the dynamical systems theory.

James J. Gibson's theory of visual perception is another work, which is strongly embodied. Gibson focuses on the continuous interactions between an animal and its environment and the role of the body on perception. He emphasizes that an animal and its environment cannot be separated; similarly, perception and action are inseparable. This paper aims to discuss the embodied and embedded ideas in Gibson's theory of visual perception. To highlight the similarities and differences, Gibson's ideas will also be compared to other research projects that advocate embodiment.

In the next section, a brief summary of Gibson's ecological approach to visual perception is presented. In Section 3, Gibson's ideas will be discussed in the context of *simple* vs. *radical embodiment* suggested by Clark (348). In section 4, first *conceptualization*, *replacement* and *constitution* categorization is introduced (Shapiro, *Embodied Cognition: New…* 4) and then Gibson's theory will be discussed in the context of Shapiro's categorization. The paper ends with a summary of the embodied and embedded ideas in Gibson's theory of visual perception.

2. Gibson's Ecological Approach to Visual Perception

Before discussing the role of the embodiment in Gibson's theory of visual perception, in this section, I will briefly summarize Gibson's ideas. A full summary of Gibson's theory is beyond the scope of this paper. Instead, I will try to highlight some of the important ideas that will facilitate the discussion on embodiment. Gibson (*The Ecological…* 1*; The Perception…* 1*; The Senses…* 1) rejected any account of perception that is based on sensations and representations, in which perception is treated as a passive process causally determined by the stimulation. He argued that unlike the impoverished retinal images, the light arriving at a point of observation is structured by the environment and this patterned light, called *the optic array*, is a rich and continuous source of information. Perception is an active process: animals actively move around in the world to sample and explore the optic array, to create and pick up the information that specifies the world properties with respect them. As the animal moves in the environment, the optic array changes, creating *the optic flow*. However, the motion of the animal does not completely change the optic array; some features persist. Thus, in Gibson's terms, information refers to higher order patterns that do not change in an otherwise changing optic array. To perceive is to pick up information; it is a continuous activity whose main function is to guide the action (Michaels and Carello 70). This means that perception occurs as an animal moves in its environment; it does not happen inside the animal's head. It arises from the relation between the animal and its environment. Moreover, the process of perceiving is always direct, i.e. it is not mediated by sensations, assumptions, expectations, inference or memory processes. The animal is in direct contact with the environment through information. The information in the optic array uniquely and precisely specifies the environment with respect to the animal because structure of the optic array is governed by natural laws. Thus, the relation between an animal and its environment is real and lawful.

Richardson et al. identify six main principles of Gibson's ecological approach, which they argue, emphasize the embodied and embedded ideas in Gibson's formulation (164). The first principle states that the proper units of analysis are the animal-environment systems (*The Ecological…* 8). Here, environment does not correspond to the physical world, which is described by physics, independently of the animals living in it. Rather, Gibson argues that *"the environment of animals and men is what they perceive"* (*The Ecological…* 15). The environment is perceived because the perceptual apparatus of the animal is sensitive to certain structures in the optic array, but at the same time, the perceptual apparatus of the animal has evolved with respected to those structures. This means neither the animal nor the environment can be considered independently of the other. Moreover, a certain structure in the optic array provides information specifying the environment as long as the animal is sensitive to that structure. Therefore, information is a relational concept, which points both to the animal and the environment and it resides in the animal-environment systems. These lead us to the second principle which states that environmental realities should be defined not in terms of physics but at the ecological scale, the scale at which animals, their environments and the relationship between animals and their environments are defined. This indicates that what is perceived and acted upon is defined by the animal relevant properties of the environment.

The third principle claims that behavior is an emergent and self-organizing process. It is the outcome of the animal-environment system. Moreover, it is considered as a reorganization of the whole animal-environment system. Time-evolution of behavior generates, and at the same time, is constrained by the information in the changing optic array. The fourth principle states that perception and action are continuous and cyclic. Gibson argued that perceptual systems are not passive; they actively detect information (*The Ecological...* 1; *The Senses...* 1). We act in order to perceive and what we perceive in turn guides the action. He rejects the separation between perception and action and defends that studying perception and studying action are of the same logical kind. However, the claim that perception and action are cyclic does not simply mean that perception and action influence or interact with each other. The claim is stronger. As Richardson et al. put it, perception and action form "a perception-action Möbius band, a depiction that realizes perception and action as continuously unified, dual aspects of an ongoing organism-environment event" (175). In other words, they are the two sides of the same coin.

The fifth principle states that information is specificational. This means that the patterns in light and the properties of the environment to which they correspond to have a one-to-one mapping. Information uniquely specifies the properties of the world by being lawful. Moreover, perception is sensitive to perceiver-scaled (relational) quantities. For example, the perception of depth is affected when interpupillary distance is decreased or increased (Wann et al. 2735). Similarly, when judging the weight of an object by holding it in the hand and hefting it, the perceived heaviness of the object is scaled by the distance between the center of mass of the object and the wrist (Amazeen and Turvey 213). Finally, the sixth principle claims that perception is of affordances, i.e., the possibilities of actions that surfaces, objects, and events offer to an animal. To illustrate, we do not perceive a chair, a cup or an apple per se but we perceive objects that are "sit-able", "grasp-able" or "edible". Affordances are dispositional properties of objects, surfaces and events. A chair is sit-able depending on who is trying to sit on it. So, affordances are relational properties. They exist in the environment as facts about the animal-environment system, not as subjective experiences. They are real, not phenomenal and directly perceptible (Bingham 1). The information specifying affordances is in the optic array for one to pick up. For example, Warren (683) showed that the perceptual category boundary between "climbable" and "unclimbable" stairs is specified by an invariant ratio of riser height to the leg length. Thus, the concept of affordance both emphasizes the mutuality of animal and its environment and the inseparability of perception and action. The perception of environment always entails the perception of the self moving in that environment.

3.Simple vs. Radical Embodiment

Clark (348) distinguishes the commitment to embodiment into two main groups: simple embodiment and radical embodiment. In simple embodiment, the main explanatory tools of the traditional cognitive science such as mental representations, internal models and computational processes that manipulate the representations are retained. The bodily and environmental facts and the interactions among them simply constrain and inform the mental representations and the processes operating on them. Barsalou's theory of perceptual symbol systems can be considered as an example of simple embodiment ("Grounded cognition" 617; "Perceptual symbol systems" 577). Barsalou ("Gorunded cognition" 617) argued that knowledge and cognition are grounded in bodily states and in the brain's modality specific systems. Those systems include the sensory, the motor and the introspective systems that underlie perception, action and conscious experiences, respectively. While emphasizing the importance of symbolic operations of traditional approaches, he claimed that cognition operates on perceptual symbols, not on amodal symbols as assumed in the traditional approaches. These perceptual symbols are schematic neural representations that reside in the sensory-motor areas of the brain. Even though Barsalou's theory highlights the importance of embodiment, the role of the body is limited to building mental representations and cognition is still explained in terms of mental representations and computational processes that manipulate them. In other words, the role of the body in perception is mostly to constrain and/or facilitate the formation of mental representations. These representations are then used to plan actions in the brain, implying that perception and action are separated from each other.

Radical embodiment is more ambitious. As Clark puts it, it treats the bodily and environmental facts as *"profoundly altering the subject matter and theoretical framework of cognitive science"* (348). Clark identifies three main claims of radical embodiment and argues that each account of radical embodiment defends at least one of these three claims. The first claim is that the traditional notions of mental representations and computations are inadequate and unnecessary to explain cognition. The second claim is that an animal and its environment are nonlinearly coupled, forming a unified system that cuts across the traditional brain-body-environment boundaries. The third claim states that the explanatory tools that are used to understand complex interaction between brain, body and environment are those of the dynamical systems theory. Based on these claims, Thelen and Smith's work in developmental psychology, (Thelen and Smith 1; Thelen et al. 1), sensorimotor theories of perception (O'Regan and Noë, "A Sensorimotor…" 939; O'Regan and Noë, "What It Is…" 79), Varela et al.'s (1) enactive approach to cognition and Gibson's ecological approach to visual perception can all be considered as examples of radical embodiment. All of these accounts reject the notions of representation and computation and emphasize the inseparability of perception and action. However, there are fundamental differences between these approaches if they are examined more closely. Despite the commonalities, the research subsumed under the umbrella of the term radical embodiment can be further distinguished according to the nature of the coupling between perception and action and the way they try to explain cognitive phenomena. I will now turn to these issues.

In their seminal work on well-known A-not-B error, Thelen and her colleagues defend that cognition arises from the bodily interactions with the world. More specifically, cognition depends on *"the kinds of experiences that come from having a body with particular perceptual and motor capabilities that are inseparably linked"* (Thelen et al. 1). A-not-B error is a perseverative error exhibited by infants of 7-12 months of age (Piaget 44). In a typical A-not-B task, two opaque boxes with lids, box A and box B, are placed within an infant's reach. An experimenter hides an attractive object, like a cookie or toy, in box A in full view of the infant. The infant reaches for box A and retrieves the object. This process is repeated several times: the experimenter hides the object in box A and the infant retrieves the object from box A. Then, the experimenter hides the object in box B in full view of the infant. Infants of 7-12 months of age still reach for box A to retrieve the object even though they saw that the object was hid in box B. Piaget originally proposed that this error stems from infants' immature concept of object permanence.

Advocating a dynamical systems approach to cognition and behavior, Thelen and her colleagues argue that, A-not-B error is not the result of an immature concept of object permanence as Piaget (44) suggested, but is due to a failure of the motor planning process, which is a part of a dynamic perception-action loop (Thelen et al. 1). It emerges from the coupled dynamics of the body, perception and the world. In their view, perception is not isolated from action; it is coupled to the actions accompanying it. They define this coupling as follows. Perception and action interact with each other throughout development. On one hand, perception helps infants guide and influence their actions. On the other hand, infants' intrinsic motor tendencies and the level of motor control in turn affect infants' perceptual abilities. Even though Thelen et al. (1) argue that perception and action are coupled, in their formulation there is still an implicit distinction between perception and action, in other words, perception and action are distinct, though strongly coupled, processes. They are different kinds.

Both Thelen et al. and Gibson agree that perception and action are inseparably linked. Both argue that perception and action are reciprocal, complementary and mutually influencing each other. However, Gibson takes this claim further and argues that perception and action are of the same logical kind. Perception is indeed an action. One aspect of this claim is that vision depends on the eyes moving in the head, which moves on a body, which in turn moves in an environment. To put it another way, if there is no motion then there is no perception. To illustrate, consider the *motion parallax*, i.e. the relative motions of the objects in the environment that are at different distances. The motion parallax, which provides depth information, is produced by the relative movement of the observer with respect to the objects. The second aspect of the claim that perception and action are the same logical kind is the notion of affordances. Gibson argued that what an animal perceives is not the objects in the environment but the possibilities of actions that they offer to the animal called affordances. Affordances are properties of the objects that are specified by the relations between the physical structure of the environment and the physical and motor capabilities of the animal. Perception is of affordances.

Thelen and her colleagues also emphasize the importance of having a body with particular perceptual and motor capabilities. For example, giving infants the ability to manipulate objects more easily by wearing sticky mittens, thus, enabling them to coordinate seeing and reaching more successfully, enhances infants' visual attention processes (Needham et al. 279). Gibson also takes this claim further and argues that body is always part of the perception in the sense that, first, perception of the environment always entails perception of the self moving in that environment; and second, animals do not perceive the environment in absolute (or perceiver-neutral) units; perceptual information is always body-scaled. For example, Warren and Whang (371) investigated the visual guidance of walking through apertures and found that the transition from frontal walking through an aperture to body rotation is specified by an invariant ratio of aperture width to shoulder width and that the perception of passability is based on body-scaled eye-height information.

Even though both Thelen et al. and Gibson argue that the behavior of an animal emerges through its continuous interaction with its environment, another difference between the two approaches is the way they try to explain behavior. Taking a dynamical perspective and employing the tools of the dynamical system theory, Thelen et al. aim to investigate how infants' perseverative behavior emerges from the coupled dynamics of reaching, memory and visual input. The task is modeled as a dynamical system. Then, the explanatory focus is on the structure of the state space and how trajectories from one state to another unfold over time under the influence of internal and external forces (Beer 91). Visual inputs to the system, such as the locations of the containers or the location of the target object, are considered as perturbations to the system's internal dynamics. Gibson, on the other hand, argued that the behavior of an animal is controlled by the information that is available to the observer. According to the ecological approach, once the information is detected, the control laws map this task-specific information to a movement variable to control behavior (Warren and Fajen 307). Control laws are considered as functions in which informational variables modulate action variables. They can be written in a kinematic form, in a kinetic form, or in a dynamical form.

Another work that can be considered as an example of radical embodiment is the sensorimotor theory of perceptual experience developed by O'Regan and Noë ("A Sensorimotor…" 939; "What It Is…" 79). Similar to Gibson, they argue that perception is an exploratory activity and the basis of perception is action dependent information. As an observer moves in the environment, the motor patterns created by the observer are accompanied by co-occurring changes in the stimulation. Sensorimotor theory argues that there are lawful and invariant relations between these co-occurring motor and sensory patterns and that the perceptual systems are able to extract these invariant relations, which are called *sensorimotor contingences*. Sensorimotor contingences are sensory in the sense that they depend on the features of the visual apparatus and the properties of the world that the apparatus is sensitive to (Shapiro, *Embodied Cognition: New…* 1). They are motor in the sense that they also depend on the activities of muscles in the body such as eye, head or body movements. Sensorimotor contingences are what constitute information for an animal and visual experience is an exercise of knowledge of sensorimotor contingences. In other words, as an animal moves in its environment, it acquires the knowledge of sensorimotor contingences and the ability to make use of that knowledge which is not propositional and generally implicit. As a result, visual experience becomes a skillful activity.

Both the ecological and the sensorimotor approaches reject any account of perceptual experience that is based on mental representations and models. Both emphasize the role of perception-action loops and the active nature of perception and both argue that perception is an act of extracting invariant aspects information that is available to the animal. However, they differ in how they define action-dependent information, i.e. perceptual invariants, and the functional role action plays in perception (Mossio and Taraboralli 1324). According to Gibson, perceptual invariants are higher order patterns in the structure of the light that are revealed and remain unchanged by the relative motion between the animal and the environment. These invariants, by being lawful (they are lawful because the patterns in light obeys the laws of geometry and physics), carry information about the system formed by the animal and its environment. To perceive is to pick up invariants. However, picking up invariants does not mean that we perceive the patterns in the light. Rather, we perceive what is specified by those patterns. For example, consider the cases when an object is rotated which is a rigid transformation, and when an object is stretched which is a non-rigid transformation. In both cases, the corresponding patterns in the light created by the motion of the object are non-rigid. If we perceived the patterns in light then in both cases we should see a non-rigid transformation. However, it is not the case. Thus, what matters for perception is not the patterns in light but what is specified by those patterns when they are detected. To sum up, in Gibson's theory perceptual invariants are action-dependent in the sense that they can only be revealed by the relative motion between the animal and the environment. Therefore, action is required to obtain perceptual information. Perception cannot occur if invariants revealed by action are not available. In other words, if there is no action, then there is no perception.

Another aspect of the ecological invariants is that the movement of the animal is only required to produce the changes in the optic array. The specific aspects of the movement do not enter into the definition of perceptual invariants. Indeed, multiple different movements can create the same transformation in the optic array, and as a result, can reveal the same invariant. For example, the motion parallax, which provides information about depth structure, can be revealed when the observer actively moves in the environment, or the observer is moved passively in the environment, or when the objects move in the environment. In each case, the same invariant is revealed. Since the invariants are defined with respect to the transformations, Mossio and Taraborelli (1324) argue that ecological invariants are transformation specific. This means that specific aspects movements do not play a critical role. As a result, the movement of the observer plays an instrumental role in the determination of the ecological invariants.

Sensorimotor invariants, on the other hand, are properties of co-occurring motor and sensory patterns. When a sensory transformation co-occurs with a movement, a sensorimotor coupling is created. Sensorimotor invariants are the unchanged properties of a sensorimotor coupling. In this case, the active movement of the observer, the passive movement of the observer or the movement of the objects in the environment will all reveal different sensorimotor invariants since in each case, the motor variables accompanying the perceptual transformations will be different. As a result, Mossio and Taraborelli (1324) argue that sensorimotor invariants are motor specific and the movement of the observer plays a constitutive role in determining sensorimotor invariants.

In addition to these two differences pointed out by Mossio and Taraboralli, (1324), I argue that the ecological and the sensorimotor approaches also differ in the nature of perception. O'Regan and Noë ("A Sensorimotor…" 939; "What It Is…" 79) view perception as a skillful activity. Perception is considered to be an exercise of the knowledge of sensorimotor contingencies. As one moves about in his environment, he gains the knowledge of sensorimotor contingencies by observing the lawful regularities between his movement and the change in the sensory stimulation accompanying the movement. This accumulating knowledge of sensorimotor contingencies creates expectations about the world and those expectations underlie perception. Gibson, on the other hand, argued that perception is pick-up of information, which is usually in the form of higher-order optical invariants. By drawing an analogy between a polar planimeter and the visual system, Runeson (172) argue that we measure higher order optical variables directly. A planimeter is a device that can measure the area of any figure regardless of its shape. Area can be considered as a higher order variable calculated from length. A planimeter measures the area without detecting the lower-order variables such as length and then performing computations on those lower-order variables. The area is measured directly through the movements of planimeter's parts. Like a planimeter, the visual system measures higher-order optical variables directly, without performing computations. For example, the optical variable tau, which specifies the time-to-contact with the objects in the world (Lee 437), is measured directly even though it can be calculated using two lower-order optical variables the image size and the image expansion rate (Todd 795). Thus, the ecological approach argues that the visual system does not compute. It is a measurement device and the evolution equipped animals with the necessary measurement tools.

Varela et al.'s *enactive approach* to cognition is yet another example of work that falls within radical embodiment (Varela et al. 1). Varela et al. reject the traditional approaches to cognition relying on representations and computational processes. Instead, they propose that cognition is embodied action. By embodied they mean that, first, *"cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities"* (172), indicating that organisms with different bodies and perceptual systems will have different sensorimotor capacities, as a result they perceive differently and act differently, and second, *"these individual sensorimotor capacities are themselves are embedded in a more encompassing biological, psychological, and cultural context"* (172). They emphasize that perceptual and motor processes, and thus perception and action, are inseparable. As an organism moves in its environment its motion creates new perceptions and in turn these new perceptions reveal opportunities for new actions. In other words, actions influence perception, which in turn influences actions, creating a perception-action loop in which it is impossible to determine the beginning, the middle and the end. Then, their formulation of enactive approach is as follows: *"perception consists in perceptually guided action and cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided"* (Varela et al. 173).

Varela et al. (1) also argue against the conception of perceptual experience as a process of recovering pre-given properties of the world from inadequate sensory data. They reject realism which defends that the world has pre-given properties which are independent of any organism perceiving it. They also reject the other extreme, i.e. idealism that denies the existence of mind-independent reality. Varela et al. argue that the enactive approach is the middle ground between realism and idealism. Their argument is as follows. Since cognition depends on sensorimotor capacities, organisms with different sensory and motor capabilities will perceive the world and act in the world differently. This indicates that the world becomes perceiver-dependent, arguing against realism. For example, an organism that can detect changes in geomagnetic field will have access to certain properties of the world which are hidden from another organism that cannot detect geomagnetic changes. As a result, each organism will perceive the world differently and will have different world conceptions. However, we also share common sensory and motor capabilities with our conspecifics. This makes it possible to share a common world conception, which argues against pure idealism. Our shared biological, psychological, and cultural history constrains how we perceive the world.

In order to explicate what they mean by the embodiment in a living system, Varela et al. (157) uses color perception as an example. I will not present Varela et al.'s complete discussion of color perception in this paper. Basically, their suggestion is that there are no colors in the world that are independent of perceptual and cognitive capacities of organisms. Rather, color emerges from the interaction between certain properties of a visual system and certain properties of the world. In other words, experience of color is a response of a properly tuned perceptual system to a certain non-colored properties in the world (Shapiro, *Embodied Cognition: New…* 1). Based on their discussion of color perception Varela et al. argues that perceptual experience neither pre-given nor represented but it is experiential and enacted.

Varela et al.'s enactive approach, O'Regan and Noë's sensorimotor approach and Gibson's ecological approach to visual experience all share common and important background assumptions such as the inadequacy of the traditional notions of representation and computation in explaining visual experience, the role of action in perception, the inseparability of perception and action, the active nature of perception, the emphasis of the body, the environment and the interaction between an animal and its environment. However, as Taraborelli and Mossio (1343) indicate, there are also differences between these approaches. Both enactive approach and the sensorimotor approach are based on the sensorimotor patterns, i.e. they share the same notion of perceptual invariant, which distinguishes them from the ecological approach. However, there is a fundamental difference between the enactive approach and the sensorimotor approach. The enactive approach puts an explicit biological constraint for a system to have cognitive and perceptual capacities. In other words, according to the enactive approach only living systems can have cognitive and perceptual capacities. However, the sensorimotor approach does not have such an explicit biological constraint. It does not reject the idea that the same sensorimotor invariants could in principle be implemented in an artificial system (Taraborelli and Mossio 1343).

In addition to having different notions of perceptual invariants, there is another fundamental philosophical difference between the enactive and ecological approaches to visual experience. The enactive approach defends that perceptual experience is not detection of a pre-given world property. Rather, it emerges as a perceptual system with certain properties interacts with certain properties of the environment. Perceptual properties (color for example) do not exist in the world. These indicate that the philosophical basis of the enactive approach is phenomenalism. However, the philosophical basis of the ecological approach is characterized as ecological realism. Ecological approach conceives perception as a relation between an animal and its environment. Perception is based on information, which resides in the animal-environment systems. The relation between the animal and the environment is real and lawful. This is what is meant by ecological realism. For example, Gibson (*The Ecological...* 127) argued that what an animal perceives is the affordances of the surfaces, objects, and events in the environment. Affordances are specified by the information that is available in the changing optic array for one to perceive. They are real, not phenomenal and at the same time they are animal-referential.

4. Embodied Cognition: The Conceptualization, Replacement and Constitution Hypotheses

Based on the goals and methods used, Shapiro (*Embodied Cognition: New…* 4) proposes another way to categorize the research falling within embodied cognition. He distinguishes three main themes: *Conceptualization*, *Replacement* and *Constitution*. He also suggests that these three categories are not mutually exclusive; many examples of embodied cognition can be considered as belonging to more than one category. The conceptualization hypothesis focuses on the relation between an organism's body and the concepts it is capable of acquiring. It argues that properties of an organism's body constrain and determine the conceptual capacities that the organism will have. Consequently, differences in bodies will create differences in conceptual capacities. Then, the goal of the conceptualization is to show that how an organism's conception of its world depends on and is constrained by its body. Shapiro (*Embodied Cognition: New…* 89) considers Lakoff and Johnson's analysis of metaphors in language (Lakoff and Jonhson 1) and Barsalou's (577) perceptual symbol systems hypothesis as examples of Conceptualization.

According to Shapiro, Varela et al.'s enactive approach to perceptual experience, too, falls within Conceptualization (*Embodied Cognition: New…* 52). Using color perception as an example, Varela et al. argued that perceptual experience is not pre-given or represented but it is experiential and enacted. It emerges when a perceptual system with certain properties interacts with some property of the world to which it is sensitive. If that particular visual system had different properties, then the organism would have different perceptual experiences. So, according to Shapiro, in Varela *et al.*'s account, the properties of the body constrain the perceptual experiences that an organism can have. As can be seen from these examples, the commitment to Conceptualization does not necessitate the rejection of the explanatory concepts and tools of the traditional cognitive science. As in Barsalou's perceptual symbol systems hypothesis, one can still explain cognition in terms of representations and processes operating on those representations, while emphasizing the role of the body in building mental representations. Or as in Varela et al.'s enactive approach, one can pursue Conceptualization and argue that cognition cannot be explained as symbol manipulation.

The Replacement hypothesis involves projects, which advocate that representations and computations are not the right tools to explain cognition, and must be abandoned in favor of new tools and approaches (Shapiro, *Embodied Cognition: New…* 114). According to Shapiro, the proponents of Replacement all share that (1) cognition and behavior emerge from continuous interactions between an organism's brain, body and environment, (2) organisms are in contact with their environment, as a result, there is no need to represent it; an organism's bodily interactions with its environment replace the representations and processes operating on those representations, and (3) since cognition (and behavior) emerges from continuous interactions, time plays a crucial role in cognition, which cannot be captured by computational theories. Thus, most of the examples of Replacement come from research projects subsumed under the title dynamical approaches to cognition, even though the use of the mathematical tools of dynamical systems theory is not a necessary requirement proposed by Shapiro (*Embodied Cognition:*

New… 116)[1]. Thelen et al.'s explanation of A-not-B error, and Brooks' behavior-based approach to robotics (Brooks, "A Robust Layered…" 14; Brooks, "Intelligence…" 139) are all considered to be examples of Replacement.

The constitution hypothesis is a reaction against the traditional approaches, which consider the constituents of cognition to be completely within the skull. It argues that the constituents of cognitive processes extend beyond the brain into the body and the environment. In other words, it claims that the body and the environment do not simply have a causal influence on cognition; they play a constitutive role in cognitive processes. For example, O'Regan and Noë argued that perceptual experience is a skillful activity constituted by our possession of sensorimotor contingencies and *"the experience of vision is actually constituted by a mode of exploring the environment"* ("A sensorimotor account…" 946). Thus, Shapiro (*Embodied Cognition: New…* 164) considers the sensorimotor approach to perception as an example of Constitution[2].

Shapiro (*Embodied Cognition: New…* 158) further distinguishes Constitution into body-involving Constitution and world-involving Constitution. He argues that the role of gesture in speech can be considered to be an example of body-involving Constitution. Rauscher et al. (226) showed that when describing situations involving spatial content, the speech of the participants was impaired when they were prevented from gesturing. Based on this result and the results revealed by many other studies, researchers argue that the function of gesture is not just to clarify communication. It is a way to structure information and contributes to the processes of thinking, that is to say, cognition extends into the body of the speaker. An example of world-involving Constitution is Clark's the extended mind hypothesis (Clark and Chalmers, 10). In their famous thought experiment, Clark and Chalmers

[1] Shapiro (*Embodied Cognition: New…* 137) gives Rodney Brooks' subsumption architecture (Brooks, "A Robust Layered…" 14; Brooks, "Intelligence…" 139) as an example of Replacement. Subsumption architecture is a layered control system for autonomous robots, in which each layer is an augmented finite state machine. Even though it is possible to provide a dynamical interpretation of Brooks' subsumption architecture (finite state machines can be defined as dynamical systems), Brooks himself does not use the language of dynamical systems theory.

[2] O'Regan and Noë, ("A Sensorimotor…" 939; "What It Is…" 79) also reject the computational view and argue against the idea that perception is based on mental representations and processes operating on those representations. This makes their theory also consistent with Replacement. However, the reason for Shapiro to consider O'Regan and Noë's sensorimotor approach to perceptions as an example of Constitution but not Replacement seems to lie in his dissatisfaction with their argument against computationalism. Shapiro (*Embodied Cognition: New…* 164) argues that the way O'Regan and Noë formulated their theory does not necessitate the rejection of the computational view.

introduce two people: Inga who has normal and intact memory and Otto who suffers from severe memory loss due to Alzheimer's disease, as a result, relies on a notebook involving all the information once he had in his memory. When Inga needs information, for example an address, she consults to her memory. When Otto needs information, he uses his notebook. Clark and Chalmers argue that Otto's notebook plays the same role as Inga's biological memory, which implies that the constituents of cognitive processes can extend beyond the brain and the body, into the environment.

Shapiro (*Embodied Cognition: New…* 178) also points to an important misinterpretation of Constitution. He states that the constitution hypothesis does not claim that cognitive processes extend beyond the brain. In other words, a person's gestures or Otto's notebook is not doing cognitive processing but they are constituents in cognitive processes. To sum up, the main claim of Constitution is that the constituents of cognitive processes can extend outside the skull, into the body and the environment. Bodies and the features of the environment can contribute to cognitive processing and reduce the load of internal system by structuring information and by cognitive offloading (such as creating shopping lists, using maps to find ways or using paper and pen to perform complex multiplications). As can be seen from the examples discussed, Constitution does not entail the rejection of the computational view of the mind.

Now that we have discussed Conceptualization, Replacement, and Constitution, we can now consider Gibson's theory of visual perception in light of Shapiro's categorization. Traditional theories of perception assume that perception is mediated and causally determined by sensations, which are created by the stimulation on the retina. They take the retinal image as the starting point for perception. Perception is considered as reconstructing the world from inadequate and impoverished retinal images through inference or memory. In other words, the brain computes and fills in all the information, such as the third dimension, that is missing in the retinal image. The retinal image provides information about the environment by virtue of being similar to the environment (for example, the image size is similar to the object size and the image shape is similar to the object shape).

Gibson rejected any accounts of perception that are sensation-based. He argued that perception is information-based. The optic array, not the retinal images, is the basis of perception. He used progressive occlusion as an argument against the sensation-based accounts. Consider the case when an object is progressively being hidden by another object. As the second object occludes the first one, it deletes the optical texture along the occluding edge. In other words, as the first object gets occluded, optical elements are progressively taken out of existence. The hidden parts of the object are not projecting any light; therefore, they are not creating sensations. Yet the object is not perceived as going out of existence. It is perceived as being hidden by another object. This is because going out of existence and going out of sight creates different patterns in the optic array, as a result, provides qualitatively different information. The most important difference is that going out of sight by an occlusion is reversible. As the observer moves or the objects move, the occluded parts of the object become visible again and reveal the information. Based on this analysis, Gibson argues that sensations cannot be the basis of perception. Perception is based on the information provided by the changing stimulation. Thus, to perceive is to pick-up the information in the optic array, which is usually in the form of higher-order optical invariants. The structure of the optic array is governed by natural laws. Moreover, it is not similar to the world structure but specific to it. Therefore, the basis of perception is natural laws. The visual system does not compute in order to perceive, it detects information. It is a measurement device. It measures higher-order optical variables directly, without performing computations. To sum up, the ecological approach to visual perception rejects the notions of sensation, representations and computations, which are the main explanatory tools of the traditional theories of perception. Moreover, it provides a new way to conceptualize perception. As a result, I argue that the ecological approach to visual perception can be best considered as an example of Replacement.

The Conceptualization hypothesis states that an organism's conception of the world depends on and is constrained by its body. The notion of affordances in Gibson's theory is consistent with the Conceptualization hypothesis. Affordances of objects and events are specified by the relations between the physical structure of the environment and the physical and motor capabilities of the animal. Gibson argued that perception is of affordances. This entails that the body of an animal constrains how the animal perceives the world. However, the Conceptualization hypothesis does not necessarily reject the explanatory concepts and tools of the traditional cognitive science, such as representations and processes operating on those representations. The rejection of these main explanatory tools of the traditional theories of perception is at the core of Gibson's theory. Therefore, Gibson's theory can be categorized as an example of Replacement.

The Constitution hypothesis claims that cognition does not occur inside an animal's head (or the brain). It extends beyond the skull into the body and environment. Gibson argued that the animal and its environment form an inseparable pair and perception does not occur inside the animal's head. It is an achievement of the irreducible animal-environment system. This means that Gibson's theory is also consistent with the Constitution hypothesis. However, similar to the Conceptualization hypothesis, the Constitution hypothesis does not entail the rejection of the explanatory concepts and tools of the traditional cognitive science. Therefore, Gibson's ecological approach to visual perception can be best considered as an example of Replacement.

5. Discussion: The Meaning of Embodiment in Gibson's Theory

Gibson rejected any account of perception that is sensation mediated. His theory starts with the distinction between radiant light and ambient light. Radiant light diverges from a source of illumination. It is homogeneous and unstructured. When light rays are emitted from a light source in an environment, they are reflected back and forth from the surfaces in the environment until a steady state of reflection is reached. This steady state corresponds to the ambient light, which is heterogeneous and structured by the environment. The optic array is this patterned light with respect to a point of observation, a point in space that could be occupied by an eye. It is a rich and continuous source of information. Perception is based on the information available in the optic array. Since the structure of the optic array is governed by natural laws, the information available in the optic array uniquely specify the environment with respect to the animal. However, animals do not passively receive this information. They actively generate and pick up the information through motion. The body explores the environment by locomotion, the head explores the optic array by head movements, the eyes explore two different samples of the optic array by eye movements. Perception is an activity, which involves the body, the head and the eyes. It arises from the relation between the animal and the environment. Thus, Gibson' rejects any kind of dualism between an animal and its environment, between perception and action.

Gibson argued that an animal and its environment form an inseparable pair. An animal cannot exist without its environment. Likewise, an environment always entails an animal living in it. That is to say, the world was not an environment before the evolution of animals. An animal perceives its environment because its perceptual apparatus is sensitive to certain structures in the optic array, and at the same time, the perceptual apparatus of the animal has evolved with respect to the structures available in the optic array. This means that the animal and its environment cannot be considered independently of each other. In this respect, Gibson would argue against the idea that the colors do not exist in the world. Given that most of the primates, birds and some insects such as honeybees and butterflies have color vision, he would argue that there must be something in the world, which forced the evolution to select color vision. To sum up, a structure in the optic array provides information specifying the environment if the animal is sensitive to that structure. This means that information is a relational concept implying both the animal and the world. It resides in the animal-environment system. The animal and its environment comprise an irreducible system. Perception cannot occur inside the animal's head or in the brain.

Gibson also argued that perception and action are inseparable, continuous and cyclic. However, the cyclic nature of perception and action does not simply mean that perception and action influence each other or interact with each other. Gibson argues that perception and action are the same logical kind. To study perception is to study action and vice versa. To put it another way, if there is no action then there is no perception (consider the motion parallax, for example). Similarly, if there is no perception, then there is no action. Perception and action are the two sides of the same coin. One aspect of this claim is explained above. Gibson considers perception as an activity. We act in order to perceive and what we perceive in turn guides our actions. Natural vision depends on eyes, which move relative to the head; head moves relative to the body and body moves relative to the environment. The motion of the body relative to the environment, including the head and the eye movements, reveals the optical invariants, which specify the environment with respect to the animal. The visual apparatus measures these invariants directly from the optic array, without performing any computations. Another aspect of the claim that perception and action are the same logical kind is the notion of affordances, which can be defined as the possibilities of action that the surfaces, objects and evens offer to an animal. They are dispositional properties of the surfaces, objects and events. Gibson argued that perception is of affordances. In other words, we do not perceive a chair per se but we perceive an object that is "sit-able". Affordances are also relational properties. A chair is sit-able depending on who is trying to sit on it. Moreover, the same object or event may have different affordances depending on the needs of the animal. For example, in addition to sitting, a chair might also afford reaching by stepping on it. Thus, affordances are properties of the objects that are specified by the relations between the physical structure of the environment and the physical and motor capabilities of the animal. They exist in the environment as facts about the animal-environment system. They emphasize the inseparability of animal and environment, perception and action. The perception of the environment always entails the perception of the self moving in that environment. The body of an animal is always part of the perception also in the sense that animals do not perceive the environment in absolute or perceiver-neutral units. Perceptual information is always body-scaled. For example, changing interpupillary distance affects depth perception, perceived heaviness of an object is scaled by the distance between the center of mass of the object and the wrist and the perception of passibility of an aperture is based on body scaled eye-height information.

To sum up, in Gibson's theory the proper unit of analysis is the animal-environment system. Perception is based on information which neither in the head nor in the environment. It resides in the animal-environment system. As a result, perception arises from the relation between the animal and environment. The body of the animal is also an inseparable part of perception because (1) perception is an activity which involves eyes moving in the head, head moving on the body and the body moving in the environment, if there is no motion, then there is no perception; (2) perception is of affordances which are defined by the relations between the physical structure of the environment and the physical and motor capabilities of the animal; and (3) perception is sensitive to body-scaled information. i.e., we do not perceive the environment in absolute units.

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