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Reconciling Competing Accounts of Picture Perception from Art Theory and Perceptual Psychology via the Dual Route Hypothesis

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Abstract

The fine and applied visual arts and perceptual psychology use conflicting accounts of picture perception. In the arts, the human ability to perceive pictured objects is characterized as learned, or conventionalized, like a "visual language" (Gombrich, 1960; Goodman, 1976; Kulvicki, 2010). In perceptual psychology, picture perception is characterized as an unconventionalized, biologically grounded ability. In this account, optical properties of light produced by pictures, not conventions, make use of biologically evolved capabilities to perceive surfaces and edges in actual environments (J. J. Gibson, 1978; J.J. Gibson, 1971; Kennedy, 1974; Lee et al., 1980; Juricevic et al., 2006; Hammad et al., 2008). The purpose of this paper is to reconcile these competing claims through Goodale et al.'s (2005) dual route hypothesis. It includes a role for learning and memory in visual processing via the ventrally located "what/how" stream, in addition to a role for visual processes that rely less on memory and learning, via the dorsally located "what" stream.

The integrated account proposed here could more clearly explain the perceptual-cognitive affordances of pictorial and symbolized information used in graphic displays by not only including culturally specific similarities and differences heavily made use of by designers trained in the arts, but also neurological phenomena that may transcend cultures, and that have been heavily explored by the biological and cognitive sciences.

Keywords: Picture perception, visual language, dual route hypothesis, ecological perception, art theory, art history, graphic representation, information display.

Introduction

The fine and applied visual arts and perceptual psychology use conflicting accounts of picture perception. In the arts, the human ability to perceive pictured objects is characterized as learned, or conventionalized, like a "visual language" (Gombrich, 1960; Goodman, 1976; Kulvicki, 2010). In perceptual psychology, picture perception is characterized as an unconventionalized, "innate" ability. In this account, optical properties of light produced by pictures, not conventions, make use of biologically evolved capabilities to perceive surfaces and edges in actual environments (J. J. Gibson, 1978; J.J. Gibson, 1971; Kennedy, 1974; Lee et al., 1980; Juricevic et al., 2006; Hammad et al., 2008). The purpose of this paper is to reconcile these competing claims through the use of Goodale et al.'s (2005) dual route hypothesis. It includes a role for learning and memory in visual processing via the ventrally located "what/how" stream, in addition to a role for visual processes that rely less on memory and learning, via the dorsally located "what" stream. An integrated account has not yet been developed for the arts, or the philosophy of art, that makes use of such newer findings.[1]

[1] As of at least November, 2010, this debate was still unresolved (Kulvicki, 2010a).

Some useful aspects of each competing account. Before proceeding further, it may be useful to review some aspects of each competing account in order to point to aspects of each that are both useful for the applied arts and for increasing a scientific understanding of graphic representation.

Much of fine and applied art makes use of phenomena that would be missed through an account that ignored conventions. Conventions include: political events, religion, historical facts, conventions created by artists, and beyond.

However, less-artistic uses of pictures may make the purely conventionalized account limiting. Professionals from the graphic arts are hired to produce representations for educational materials. These representations must take into account individual similarities and differences. These are both cultural and perceptual-cognitive. Such a task could be aided by an account based in the cognitive neurosciences. For example, a student with dyslexia or autism has a neurological configuration that is distinct from normal controls. An account from the cognitive neurosciences could help lead to more effective picture and symbol use in materials that accommodated differences.

Hence, this divergence has more than academic implications. As graphic representations are increasingly used in information displays, particularly in IT and education, a principled scientific account that could inform the design of graphics is increasingly being called for (Ware, 2008; Ramadas, 2009; Moody, 2009).

Relevance to cognitive science. An integrated account could also extend the scope of cognitive science because a unified framework would span both fields. Artistically created and related cultural phenomena could more easily be described by cognitive scientists and art theorists alike using terms and methods familiar to domains such as visual cognition and cognitive linguistics. The extended scope would include phenomena that are inherently multi-modal, but also materially, and culturally, situated.

Thesis. The first part of the claim made here is that the ventral "what/how" stream's memory systems enable actual and depicted objects to be taken as *symbolized information*, corresponding to the conventionalized account used in the arts. Visual processes of the ventral stream produce and make use of traces ("memories") from previously visually processed objects to inform the selection of potential actions, such as a particular kind of grasping action, (Goodale et al., 2005), using the same or similar memory systems used for language (Martin et al., 2001).

Once a particular action is selected, so-called dorsal "where" processes of the human brain, which are "trapped in the moment," and that appear to rely less on memories, direct the selected action in relation to target objects visually processed in real-time (Goodale et al., 2005). Thus, the second part of the claim made here is that these real-time visual processes correspond to the optical account from perceptual psychology, where processing of actual and pictured features relies less on prior learning and memory. Information processed in this way is referred to here as *pictorial information*.

Scope and limits. This paper will focus on this particular unresolved issue, the debate between proponents of conventionalized and innate-optical accounts, by responding to a rare exchange between art and science disciplines. This debate was sparked by Ernst Gombrich, a noted art historian, and J.J. Gibson, and will be highlighted in the next section.

A schema that presents each account in relation to competing accounts is shown in Figure 1.

Key Terms

Clarifying several key terms may aid the reader. By *"innate-optical account"* I will refer to theories that claim picture perception occurs independently of conventionalized processes. By *"conventionalized account"* I will refer to theories that claim picture perception is only possible because of learned social-cultural conventions. *"Dual processing account"* refers to Goodale et al.'s (2005) hypothesis that I will use to integrate the conflicting views. It is itself a biologically based account, but one that includes a role for prior experience, the basis for conventions, in perception. Pictures are difficult to characterize at this stage because of the conflicting accounts that a characterization would rely on. For now, I would characterize a picture (building on Kennedy, 1974) as *"a surface, which on inspection, allows observers to report on things that are not present. These are representational pictures, and contrast with non-representational or abstract pictures."* I note that this characterization could also include symbols that would not ordinarily be considered pictures, so I add the further clarification that symbols also allow observers to report on things that are not present, but refer to objects or ideas other than what is presented on the surface.

Outline of Paper

To support the proposed thesis, the following section first provides a historical context by describing how the disagreement emerged from the debate sparked by Gibson and Gombrich. Next, a representative example of the innate-optical account is presented, followed by a representative example of the conventionalized account. This sets the stage for a correlation between conventionalized and innate-optical accounts and particular streams proposed in the dual route hypothesis. A model of encoding and retrieval is used to describe how categories, that enable conventions, emerge from repeated perception and recognition of objects. The paper concludes with a preliminary version of an integrated account.

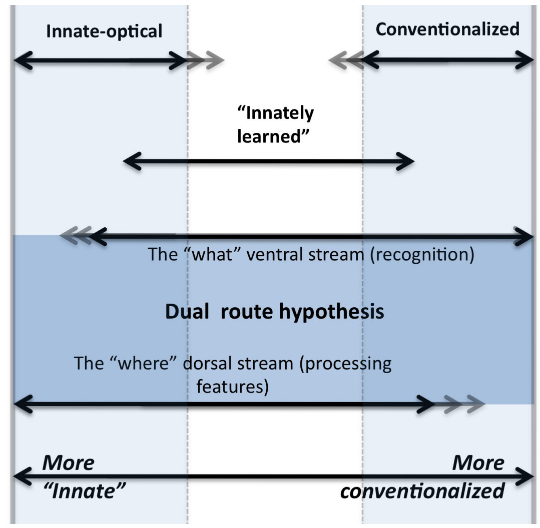

Figure 1: Each view is marked along a spectrum. *"More innate"* increases to the left. *More conventionalized* increases to the right. The *"innate-optical"* account is marked at the upper left, and is shown in contrast to the *conventionalized* account at the upper right. *"Innately learned,"* at the middle, refers to processes that are learned, but that could be learned in similar ways across populations that develop in environments with similar properties. Below this is the *dual route hypothesis*, used in this paper as a way of integrating the competing views.

Competing Accounts of Picture Perception

The Gibson-Gombrich Debates

The Gibson-Gombrich debates in the late 1960s and 1970s are noted here for historical context. The debate began when Ernst Gombrich, an art historian, wrote a highly influential book called *Art and Illusion: A Study in the Psychology of Pictorial Representation* (Gombrich, 1960). In a review, Gibson's (Gibson, 1960) critique included a refutation of the conventionalized account via his own innate-optical account. Though Gibson, Gombrich, and then Rudolf Arnheim (Gombrich et al., 1971), followed by Nelson Goodman, continued the debate, a resolution was not forthcoming and the central issue addressed by the thesis of this paper was exposed in the debate, in addition to other issues that will not be addressed here.

Goodman further developed the conventionalized account in *Languages of Art* (Goodman, 1976), which is used below. The conventionalized account became solidified in art theory, philosophy of art, and other branches of philosophy. The innate-optical account continues in the field of perceptual psychology (e.g., Kennedy, 1974; Lee, 1980; Hammad et al., 2008).

An Innate-Optical Account of Picture Perception

For Gibson, pictures make use of an organism's biological capabilities to perceive visual information. Thus, the description of Gibson's theories of picture perception will begin with a review of his theory of visual information and direct perception, followed by his theory of picture perception (J. J Gibson, 1978; J. J. Gibson, 1978).

Visual information. Following Gibson, light reflects from environmental surface features to observation points. The light from a particular observation point has a unique structure, called an optic array, which corresponds to surface features. An optic array at one position is different than one in another position (e.g., the basis for disparity). Some properties of the array change when moving between observation points, but not all. Invariants specify surface features. Invariants in optic arrays are visual information (Gibson, 1966 and 1969).

Pictorial information. Following Kennedy (1974), pictorial information is when one layout of surfaces can be artificially treated and arranged to provide visual information for or about a different environmental layout. These surfaces, on inspection, allow observers to report on things that are not present. These are representational pictures. As Kennedy (1974) stated: "That which is present in the optic array from the picture is a frozen, perhaps exaggerated, moment in the set of transformations that would reveal the invariant."

Kennedy (Kennedy, 1974) further supported this innate-optical view using several examples from the literature of the time. In the first example, Hochberg and Brooks (Kennedy, 1974) citing (Hochberg & Brooks, 1962) observed a child raised in an environment that was devoid of pictures, such as photographs and outline drawings. Later, the child was able to perceive and recognize objects represented in outline drawings and photographs without being trained to do so, thus supporting an account where the child perceived and recognized the represented objects without being taught a "visual language."[2] Persuaded by this and considerable other evidence, what is referred to here as the innate-optical account is common in perceptual psychology. However, outside of psychology, and in the visual arts in particular, this innate-optical account of picture perception is not well accepted, and is often rejected, particularly after the arts increasingly rejected positivist accounts, and perhaps because biological accounts of the time could not account for the numerous cultural phenomena that artists made use of in their works.

Discussing Gibson

I suspect that a Gibsonian would agree that although a member of another culture unfamiliar with pictures would, for example, recognize a line drawing of a piece of fruit, such as an apple, the Gibsonian would probably also agree that a member of this other culture would not recognize a line drawing with a particular learned meaning from outside of their culture (e.g., the outline drawing of an apple fruit that denotes Apple *Corporation*). I introduce this obvious strawman here to demonstrate an implicit role in the Gibsonian account of picture perception for a conventionalized capability that makes use of the innate-optical capabilities described. This is one of the keys to the bridge that will make integration possible. Prior to discussing this integration, a more precise review of the conventionalized account follows. As each account is discussed, it may aid the reader to refer to Figure 1, where each account is related to other accounts in the schema.

[2] This example represents one of the most confusing aspects of this debate. Is the ability to recognize the objects "innate," or is the ability "innately" learned? These processes could be learned in similar ways across populations that develop in environments with similar properties (see Figure 1, middle).

A Conventionalized Account of Picture Perception

Goodman (1976), building on Gombrich (1960), presented an account of picture perception that also stands in contrast to the innate-optical account from Gibson. For Goodman, almost any picture may represent almost any other thing. For Goodman, pictures, and their relation to objects, are parts of a constructed system of representation.

Pictures as labels. Goodman claimed that pictures are labels, like linguistic predicates: "just as a red light says 'stop' on the highway and 'port' at sea, so the same stimulus gives rise to different experiences under different condition" (Kennedy, 1974) citing (Goodman, 1968, 14).

Syntactic denseness. Goodman claimed that what distinguishes pictorial labels from other denotation systems, such as language, is their syntactic denseness (Giovannelli, 2010) citing (Goodman 1976, 226-227; Goodman, Elgin 1988, Chap. 7). An artist changes the meaning of a picture if they change the details of the picture, for example. If a smile is turned into a frown, the meaning changes. Changing the colour of a character's shirt changes the meaning too, if that shirt is relevant to a narrative or experience.

Critique of resemblance. Goodman did not deny that pictures can resemble their referents, but claimed that any object in some way can resemble any referent, and therefore a learned conceptual category is required in order to focus attention to the correlations that are meaningful in a particular social or cultural context. For example, all objects contain molecules, and therefore resemble each other. As Goodman claimed, "there is no innocent eye [...]. Not only how but what [the eye] sees is regulated by need and prejudice. [The eye] selects, rejects, organizes, associates, classifies, analyzes, and construct" (Giovannelli, 2010) citing (Goodman, 1976, 7-8).

For Goodman, even perspective and realism is arbitrary (Giovannelli, 2010) citing (Goodman 1984, 127). For Goodman, the amount of information is not altered, for instance, by switching from the realistic mode of representation of conventional perspective to the non-realistic mode of, say, reverse perspective (Giovannelli, 2010) citing (Goodman 1976, 35), because the rules of perspective, he claims, are conventionally established (Giovannelli, 2010) citing Goodman (1976, 1019).

Thus, for Goodman, realistic pictures are those that are depicted using a familiar system of correlation. To put it metaphorically, for Goodman, one always relies on a key to read a picture. This key must be learned.

Discussing Goodman Does Goodman's conventionalized account completely rule out the role of innate biological processes? Even if one were to completely accept Goodman's claim that the ability to perceive an object is conventionalized, a perceiver still must access light rays to be made use of by conventionalized capabilities. On the most basic level, this requires eyes. Certainly, Goodman would never claim that eyes are anything other than biological structures that are genetically inherited, even if conventions somehow govern the use of those eyes and other processes for perception. Thus, there may be an implicit role for innate-biology in Goodman's conventionalized account. The point of debate may have more to do with where picture perception relies on conventions that build on top of, or make use of, innate biological processes (see Figure 1). This is precisely the solution that is possible by making use of the dual route hypothesis, reviewed next.

Dual Route Hypothesis (Goodale et al., 2005)

Independently of the debates above, Goodale et al. (2005) proposed their hypothesis used here to integrate competing accounts. Goodale et al. (2005) identied two distinct, but interrelated perceptual-cognitive processes. *"Vision-for-perception,"* was distinguished from *"vision-for-action."* To introduce this distinction, Goodale et al. began by noting that evolution must have been driven by the need to direct movements in response to changes in the world, and perception was a step in that process. The capability for even more flexible and adaptive behaviours due to predictive abilities is possible because of complex cognitive operations on mental simulations of the world.

Distinct functions of the two streams. In this view, it is the dorsal stream that provides for real-time control of motor actions. In contrast, the ventral stream provides the rich and detailed representation of the world required for cognitive operations such as recognition, identification, and prediction. For example, the dorsal stream may allow us to reach out and grasp objects, however it is trapped in the present. The dorsal stream can deal only with objects that are visible when the action is being programmed.

Lesion studies. Lesion studies can demonstrate the roles of these systems. These studies show how patients with lesions in the dorsal stream can have problems using vision to form their grasp or to direct an aiming movement towards objects presented outside of foveal vision. This deficit is often described as optic ataxia. The opposite pattern of deficits and spared visual abilities has been reported in patients with visual form agnosia, where the brain damage is concentrated in the ventral stream.

Discussing the Dual Route Hypothesis

- A memory agnostic "trapped in the moment" process keeps the organism referenced to its environment in real-time. This is *visually processing qualities about the environment without making use of memories, and corresponds to the innate-optical account.*
- A recognition process consists of linking the present moment to memories from the past in order to form possible actions. This is an object referencing a memory, prediction, or idea. *This linkage to the past and future possibility is meaning, and corresponds to the conventionalized account.*

Figure 1 presents how I propose dual processing account relates to the other discussed accounts.

How the Competing Accounts Can Be Taken Synergistically

This section will now note how conventionalized and innate-optical accounts are not mutually exclusive and make use of independent but interrelated neural systems that enable survival in dynamic environments. As mentioned, both innate-optical and conventionalized accounts seem to implicitly require a role for the competing view.

The point of debate seems to have more to do with where picture perception relies on conventions that build on top of, or make use of, processes that rely less on conventions for perception. This is where the dual route hypothesis has explanatory power, because it integrates perceptual-cognitive processes that require learning with those processes that may not. The next subsections details points of integration, and through lesion studies, exposes the problems that emerge by not including both accounts in a theory.

Visual processing for action is possible without conventions, supporting the innate-optical account. Actions guided by visual processing of pictured surfaces and edges are possible without learned conventions, but recognition requires learned conventions. For example, patients with object agnosia have memory deficits in regions connected via the ventral stream. However, many people with object agnosia can correctly engage in (e.g., grasping) actions in relation to actual and pictured surfaces and edges, but are unable to recognize those surfaces and edges as particular objects (Goodale et al., 2005). This example strongly correlates with the innate-optical account where learned conventions are not necessary to "perceive objects" in pictures (Kennedy, 1974; Gibson, 1978). Learned conventions are not always required for visual processing for action, but are required to recognition.

Recognition requires learning and memories, supporting the conventionalized account. The ability to recognize an object, or in other words, perceive objects meaningfully by making a connection to a personal narrative of past experience traces and predicted possible actions, arises from the ventral streams interaction with other more anterior and lateral regions that are multi-modal. The ventral stream still codes for complex visual information, such as that which supports visual representation of objects bereft of meaning. Categories emerge through experiences, and solidify through repeated experiences (Goodale et al, 2005). This shares common properties with Goodman's conventionalized account of "pictures as labels" and the role of a conceptual framework in enabling a particular object to reference another object or idea (Goodman, 1976). More about the emergence of categories is detailed in the next section, using Barsalou's (2009) model of encoding, recognition, and retrieval.

Goodman's (1976) critique of resemblance pertains to recognition, but possibly not visual processing. Goodman claimed that any feature of an object or picture could be taken to resemble any other object or picture, and therefore, a learning process was required to train a perceiver to recognize the key features of an object that can be taken to refer to other objects. Once again this has the following common features as the role of memory in enabling the creation of a hierarchical schema in the ventral stream (e.g., Moscovitch, 1992; Goodale, 2005).

Goodmans (1976) syntactic denseness claim may correspond to ventrally connected memory structures that are also associated with language. Interestingly, ventrally connected memory systems are also made use of by language and object recognition alike (e.g., (Martin & Chao, 2001)). A language-like role in object recognition[3] corresponds to Goodman's (1976) picture-as-name account. So what then, is the key difference between pictures and language? Goodman (1976) claimed that pictures and spoken language are conventionally based like language, but that pictures are more "syntactically dense" than words. Whereas a Gibsonian would have drawn a distinction between language and visual perception, thus disagreeing with Goodman's "visual language" account, using the dual route hypothesis, it appears that two processing streams of the same object occur simultaneously, but one has "language-like" attributes. The ventral processing of visually perceived objects could be taken as language-like, and syntactically dense (extrapolating from Goodale et al., (2005) in light of Goodman (1976)).

What is at issue. At this point, it seems that a case can almost be made for a claim that would show how the conventionalized account is talking about picture recognition and makes use of recognition-for-prediction. It seems that a case could be made for the claim that the innate optical account is talking of picture perception, and is a process that makes use of neural systems for perception-for-action.

However, prior to making this claim that the two accounts are not mutually exclusive and make use of two interlocking neural systems that enable survival in dynamic environments, a few notes to clarify the distinction between perception-for-action and recognition-for-prediction follow.

Some Notes about Perception versus Recognition, Concepts, Categories, and Mechanisms for Conventionalization

To conceive of the mechanisms that enable conventionalization, it may be helpful to note some distinctions between (learned) recognition-for-prediction relative to (less-learned) perception-for-action. To conceive of the distinction, some simplified notes regarding encoding and retrieval, to provide a biological view of the emergence of learned categories that enables recognition, are noted here, by drawing from Barsalou (2009). Here, I take conceptual categories as the basis for conventions that pictures, including ones that are taken as symbols, make use of.

Perception (encoding). When features (e.g, of an apple #1) are perceived, detectors fire for edges, surfaces, color, etc. Conjunctive neurons in association areas capture the activation pattern. Populations of conjunctive neurons code the pattern, with each individual neuron participating in the coding of many different patterns. Local association areas near a modality capture activation patterns within it (e.g., visual features of apple #1). I refer to these consolidations here as memory traces. **Cohesion and consolidation**. Higher association areas in temporal, parietal, and frontal lobes integrate across modalities, particularly when conscious attention is applied to a feature. This architecture has the functional ability to produce modal re-enactments (simulations).

Recognition (retrieval). Now suppose there is an apple #2. Once again, feature detectors fire, but for apple #2, memory traces from apple #1 are made use of. Because a trace is linked to other aspects of the prior experience, those prior experiences are reconstructed, perhaps in consciousness (simulated), from the traces. This is recognition, recollection, or remembering, which itself leaves additional traces. This process, typically involving conscious attention, is conceived of as the basis for learned conceptual categories. Here, this emergence of categories enables the symbolization of information through repeated perception and recognition.

Toward a Unified Framework

Here, I will attempt to show how conventionalized and innate-optical accounts make use of two distinct, but interrelated, visual processing streams.

Perception-for-action enables an organism to react to changes in real-time. Organism that can simulate possible actions (predictions) can react to future changes, thus enabling survival in dynamic environments. Learning would be the organism's capability to construct predictions from traces of past percepts ("memories"), and is conceived as the basis for conceptual categories. Recognition-for-prediction enables what has been learned to be retrieved for forming a prediction prior to a (future) reaction. These processes approximately fall along two separate but interrelated streams. Dorsal processes reference action targets to the body in real time, while ventral processes connect to mechanisms that enable recognition, retrieval, and prediction.

Back to pictures. What this means is that humans can react to visually processed actual or pictured features without being trained to do so, supporting the innate-optical account. Dorsal "trapped in the moment" processes are implicated. Authors of representations can make use of this ability to

[3]Following evidence collected by Barsalou (2009), the view taken here is that memories are inherently situated, multi-modal, and stored as traces in the same systems used for perception. Concepts and categories follow the same situated and multi-modal pattern. In this view, visual language is possible.

communicate via depictions. *Because these depictions make less reference to traces from the past, the optical structure of the visual information produced by the depictions carry the majority of the meaning intended by the author.* This meaningful optical structure is referred to here as *pictorial information*.

However, recognizing visually processed features as objects requires processes that make use of traces from previously processed features. Ventrally connected memory systems are implicated. Creators of graphic representations can make use of this recognition capability to create representations that reference traces from the past. Here, this is referred to as *symbolized information*. For example, when someone visually processes a graphic representation, the aspect of the processed information that is meaningful because of the prior experiences referenced is symbolized information.

In the account proposed here, every graphic representation contains pictorial and symbolized information, but to varying degrees. For example, when someone visually processes the optical structure produced by a graphic representation, the aspect of the visually processed information that is meaningful independently of prior experience is pictorial information. When the properties of the pictorial information enable retrieval of simulations constructed from learned conceptual categories and conventions, this is referred to as symbolized information.

Conclusion

In this paper, an attempt at resolving a classic disagreement between the fine-applied arts and the psychological sciences is initiated. Newer theories from cognitive neuroscience provide a way to integrate accounts that previously seemed irreconcilable. This integration shows how each view can be reconciled with competing views by showing how humans use evolved capabilities to create pictorial and symbolized information.

This integrated account could more clearly explain the perceptual cognitive affordances of pictorial and symbolized information in graphic displays.

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