Iconic Representation

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Pictures, maps, diagrams, and gestures are **iconic representations**. They convey meaning in a way that is fundamentally different from language. Where words bear an arbitrary relationship to what they express, iconic representations encode content through structured correspondences between their form and what they represent. Iconic representation is central to human cognition and communication: it underlies the perception of space and magnitude, the interpretation of pictures and maps, the production of gesture and sign language, and the recent advances in computer vision and artificial intelligence. The concept of iconicity originated in the theory of signs, but has since developed through waves of interdisciplinary research in cognitive science. Once defined narrowly in terms of resemblance, iconic representation is now understood using a range of flexible theoretical tools. Ongoing debates concern the semantic properties of icons, the role of convention, and the status of iconic representation in perception. Broader connections link iconicity to artificial intelligence, the emerging field of super-linguistics, and the study of multi-modal communication.

1 History

The concept of iconic representation was introduced at the end of the 19th century by the philosopher and logician Charles Sanders Peirce (1998), who used it to define a broad class of signs that included pictures, maps, diagrams, and 3D models. For Peirce, **icons** formed one of a triad of sign types along with **indexes** and **symbols**. He defined icons as signs whose meaning is governed by resemblance. Symbols, which include words and sentences, were defined as those signs whose meanings are determined by convention and usage. Finally, indexes, which included the likes of weather vanes and demonstrative pointing, fix meaning by physical connection to their subject matter.

At least since Plato's idea of art as *mimesis*—the imitation of nature—philosophers have recognized the distinctive connection between images and what they represent. By situating this idea within a broader theory of signs, Peirce framed iconicity and symbolic language as two distinct but equally systematic strategies for the expression of meaning.

After Peirce, the study of iconicity has evolved in roughly three waves, leading up to the present. The works of Peirce and his contemporary, Ferdinand de Saussure (1959), gave rise to **semiotics**, the self-described "science of signs," which drove the first wave of iconicity research from the 1940s into the 1980s. Semioticians expanded the range of iconic phenomena beyond technical signs, to include the rich variety of communication in everyday life—from facial expressions and vocal imitation to advertisements and traffic signs (Nöth, 1990). While semiotics as a discipline arguably never achieved a stable scientific methodology, it made lasting contributions to the structural analysis of diagrams, maps, and film (Metz, 1974; Bertin, 1983), the study of social and political meaning in images (Barthes, 1977), and the empirical understanding of iconicity in language (Dingemanse, 2018).

Starting in the 1960s and extending through the 2000s, a second wave of interest in iconicity—or its cognates, *analog*, *depictive*, and *map-like* representation—emerged across the cognitive sciences. Within cognitive psychology, researchers investigated iconic and echoic memory, analog magnitude representations, number representation, and mental imagery, sparking a high-profile debate between *pictorialist* and *descriptivist* accounts of mental representation (Carey, 2009; Pylyshyn, 2003; Kosslyn et al., 2006). In parallel, psychologists established the perception and comprehension of pictures, maps, and diagrams as a legitimate area of empirical study (DeLoache et al., 2003). Within logic, a series of seminal studies demonstrated that diagrams and maps could support formal deduction with a rigor that paralleled symbolic logic (Shin, 1994; Allwein and Barwise, 1996; Casati and Varzi, 1999). Meanwhile, linguists documented a rich inventory of iconic phenomena in the lexicon, in gesture, and in sign language (McNeill, 1992; Liddell, 2003). And philosophers advanced detailed theories of depiction, iconic mental representation, and the structural and semantic properties of icons (Block, 1983; Camp, 2007). The rise of computer graphics during this period also yielded a computational understanding of image-making, from ray tracing to nonphotorealistic rendering, which laid the groundwork for the computational understanding of images and image-making (Durand, 2002). Work in the second wave of iconicity research was carried out against the backdrop of widespread focus on linguistic analysis and symbolic computation. In this context, iconicity was often considered peripheral to scientific and philosophical study. Critics found iconic representations to be incomplete, vague, inaccurate, or merely supportive (Fodor, 2008, ch. 6), and iconicity researchers often went to lengths to overturn these assumptions (Shin, 1994).

Philosophical analysis of iconicity did not begin in earnest until the late 1960s following Nelson Goodman's influential arguments that resemblance could be neither sufficient nor necessary for representation (Goodman, 1968, ch. 1). Around the same time, Umberto Eco mounted a critique of iconic resemblance from a semiotic perspective (Eco, 1976). Both Goodman and Eco concluded that iconicity was not in fact a genuine scientific category, and pursued alternative taxonomic projects. But as the concept of iconic representation continued to prove useful within cognitive science, many philosophers began to question the simple identification of iconicity with resemblance. This prompted a renewed search for alternative foundations (Shimojima, 2001).

Since the 2010s, a third wave of iconicity research has emerged, characterized by greater synergies and knowledge sharing across the cognitive sciences. This era has brought a major expansion in the range of empirical examples under consideration, as research shifts toward more naturalistic and multi-modal cases, including maps, sketches, iconic expressions in sign language, co-speech gestures, comics, and film (Patel-Grosz et al., 2023; Tversky, 2019). And there is growing interest in the status of iconic representations in neuroscience and psychology (Beck, 2018; Quilty-Dunn, 2020; Block, 2023). Formal methods once confined to the study of language—such as syntax, formal semantics, discourse analysis, game theory, and machine learning—are now widely applied to the study of iconic representation (Giardino and Greenberg, 2015; Patel-Grosz et al., 2023). Philosophical analysis of iconicity has likewise turned towards increasing formal and empirical ambitions (Shimojima, 2015; Camp, 2018; Greenberg, 2023). And the dramatic growth of vision science and computer vision over the past three decades have propelled image-based computation to the forefront of theoretical study (Kriegeskorte, 2015).

2 Core concepts

Sign, content, and system

Representations are physical states that function to encode meaningful content. Representations that are public, as opposed to those in the mind or brain, are known as **signs**. Signs include symbolic representations like spoken words and sentences, as well as iconic representations like Venn diagrams and line drawings. Signs are normally individuated in terms of their intrinsic **form**, or structural features. The form of a line drawing, for example, consists of a geometric arrangement of lines on a 2D plane, whereas the form of a sentence is a hierarchical arrangement of linguistic elements.

The **content** of a sign is the *literal* aspect of its meaning: the information that a sign functions to make explicitly available to its audience. For example, the content of a perspective drawing specifies a 3D scene, the content of a Venn diagram is a collection of set-theoretic relations, and the content of a declarative sentence is a proposition. To **interpret** a sign is to compute an acceptable mapping from signs to contents, given a context.

Finally, a **system of representation** provides the link between a sign's form and its content. Generalizing the concept of a language, a system specifies a domain of possible signs and semantic rules that map signs to meanings. Like languages, iconic systems such as perspective line drawings, Venn diagrams, and directed graphs each demand their own iconic semantic rules (Giardino and Greenberg, 2015). Iconic representation as a whole is often assumed to correspond to a distinctive and natural class of such systems (see Figure 1).

Sign	**System of Representation**	**Content**
Word	Lexicon	Lexical content
Sentence	Language	Propositional content
Picture	System of Depiction	3D Scene
Venn Diagram	Venn System	Set Relations

Figure 1: Systems of representation.

What is the defining feature of iconic systems of representation? Following the basic ingredients of representation—sign, content, and system—each of these may serve as a potential distinguishing dimension of iconic representation.

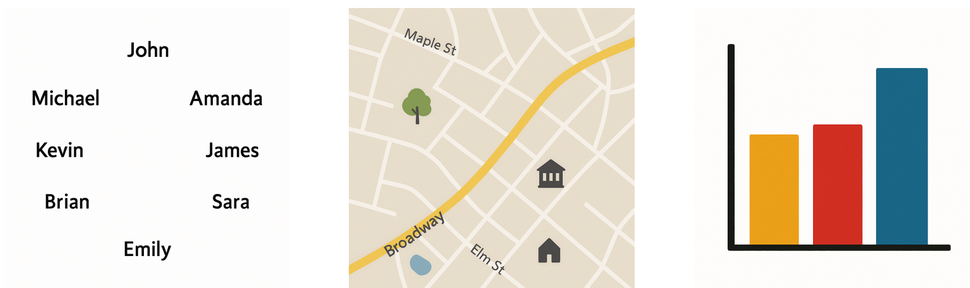
Among sign systems, iconic systems make use of a distinctive range of sign forms, contents, and semantics (Shimojima, 2001). For example, many iconic signs have two-dimensional forms—bar graphs, maps, and Venn diagrams are all examples—while expressions in spoken languages are articulated as one-dimensional strings. Likewise, iconic systems tend to assign contents that vary along continuous feature dimensions, in contrast with the discrete logical contents of language (Haugeland, 1991). To be sure, there are exceptions: Venn diagrams and directed graphs, for example, both involve discrete structures and logical contents. The common theme, however, is that icons are typically enlisted to express content that is too granular or dense to be manageable in language, and their forms tend to reflect this demand.

Today, most theorists hold that what is truly distinctive about iconic sign systems is the *way* that content is encoded by the form of the sign, rather than features of the sign or the content alone. The content of an iconic sign depends in some substantive way on the sign's form; thus the geographic content of a map is determined by its spatial layout, and the quantitative content of a bar graph by the height of its bars. This form-dependency contrasts both with the arbitrariness of symbolic representation and with the context-dependency of indexical representation (de Saussure, 1959; Greenberg, 2023).

The forms of signs come in different degrees of structural complexity (Camp, 2007). **First-order** signs are contentful representations that are structurally atomic, lacking any contentful constituents. Examples include individual words (within sentences), individual bars (in a bar graph), or isolated gauges (as in a thermometer). **Complex** signs are formed by applying **second-order** rules of combination to first-order signs. The resulting complex structures are made up of first-order atomic elements organized into syntactic, metrical, and topological structures, among others.

Thus, bar graphs, pictures, and sentences are all complex in the sense that they are built up from simpler meaningful elements.

It is important to note that a system may use some aspects of a sign to represent iconically, while other aspects are used non-iconically. Thus in complex representational systems, there is often variation in iconic status between first- and second-order structural organization (Greenberg, 2023). For example, in a seating chart, the first-order atomic elements are words—paradigmatically non-iconic signs—but the second-order structure is essentially map-like and iconic. Inversely, in a bar chart, the first-order elements are scalar bars—a clear case of iconic representation—but their second-order sequential organization on the page is often non-iconic and arbitrary (see Figure 2).



(a) (b) (c)

Figure 2: Orders of complexity. (a) A seating chart uses symbolic first-order elements (words) in an iconic second-order spatial layout. (b) Maps combine iconic and symbolic first-order elements into an iconic second-order structure. (c) A bar chart uses iconic first-order elements (bars) in a non-iconic second-order arrangement.

Resemblance and isomorphism

The traditional conception of iconicity is as representation based on **resemblance**, understood as the sharing of selected properties and structure. For example, maps have been thought to have the same spatial structure as the terrain they represent; and pictures have been thought to give rise to optical arrays (or visual experiences) that have the same spatial organization as those elicited by the scene depicted (Neander, 1987).

To extend this idea to diagrams and other non-pictorial icons, scholars have enlisted the concept of **isomorphism** (or its variants), a generalization of resemblance that describes similarity of abstract relational structures. For example, a timeline is isomorphic to the history it represents because spatial relations on the timeline may be mapped 1-1 with temporal relations in the history. Thus, even though a 2D timeline and a history of events don't *resemble* one another with respect to their first-order properties, they may still stand in a significant relation of isomorphism. Because of its generality, many theorists have proposed isomorphism as the defining feature of iconicity

(Burge, 2018; Clarke, 2022; Lee et al., 2023; Block, 2023).

However, there is ongoing debate about whether isomorphism-based analyses can accommodate the full variety of iconic representation. One issue is that isomorphism only applies to complex structures composed of representational parts; yet first-order analog gauges, like thermometers or fuel gauges, lack parts but appear iconic in other respects (Peacocke, 2019; Maley, 2011; Block, 2023; Greenberg, 2023). In addition, many mathematical transformations that undergird iconic representation—such as scalar multiplication in scale maps, or pictorial projection in depiction—are not relations of isomorphism. These transformations preserve important structure but also introduce necessary differences between their relata (Goodman, 1968; Greenberg, 2021).

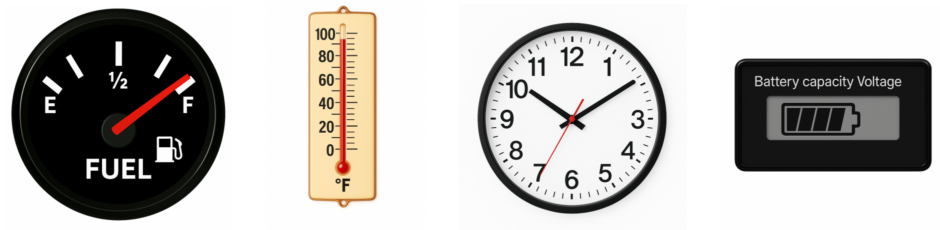
In response to difficulties of this kind, some have proposed to move from standard isomorphism, between the internal structure of a sign and the internal structure of its content, to a higher level **second-order isomorphism**, between the whole set of signs in a system and the whole set of contents. In second-order isomorphism, overall similarity relations between signs are thought to map 1-1 onto overall similarity relations between contents. Intuitively, the thought goes, in iconic representation, small changes to the sign result in small changes to the content (Shepard and Chipman, 1970; Block, 2023).

A further response is to seek a broader notion of iconicity that includes isomorphism but also accommodates differential transformations and first-order icons. Some have proposed to make use of the concept of **natural relations** between sign and content to capture an intuitive notion of *mirroring* without the formal strictures of isomorphism. It remains to be seen whether naturalness can be made precise; it has been defined in terms of human psychology (Giardino and Greenberg, 2015), the tools of natural sciences (Burge, 2018), or universal mathematical structure (Greenberg, 2023). However naturalness is defined, it gives voice to the intuition that iconic representational forms are intimately connected to their contents, in contrast with arbitrary sign-meaning pairs of symbolic language.

Varieties of iconicity

The range of iconic representational systems in human use is vast. Early semiotic inquiry focused on artifacts, such as pictures, maps, or diagrams, and these have often served as the point of departure for later explorations of iconicity in language and in the mind. The basic taxonomic distinctions are as follows.

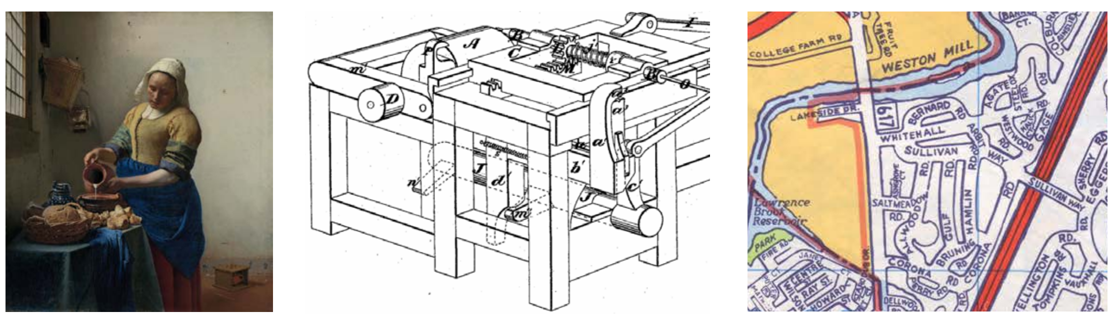
Analog signs are structurally simple iconic signs which employ magnitudes along a single dimension in the sign's form to iconically represent magnitudes along a single dimension in the world (Peacocke, 2019, ch. 2; Maley, 2011). Such representations include gas gauges, thermometers, radial clocks, and analog scales (Figure 3).



Fuel Gauge Thermometer Analog clock Battery meter

Figure 3: First-order iconic signs: gauges, meters, and other analog representations.

Most of the familiar cases of iconicity, such as pictures, maps, and diagrams, involve complex structures that combine simple elements in iconically significant ways. The class of **pictures** includes photographs, mechanical drawings, paintings, and sketches. Pictures are complex signs that organize first-order marks (lines or colors) into 2D metrical layouts in order to express 3D scenes as contents. The spatial contents of pictures are always **viewpoint-centered**, meaning that pictures always locate objects in space relative to an implicit viewpoint, and can only be assessed for accuracy relative to that viewpoint (Giardino and Greenberg, 2015; Greenberg, 2021). There are nevertheless many forms of pictorial representation. Pictorial systems vary with respect, at least, to their overall treatment of projective geometry (e.g. perspectival, curvilinear, orthographic), the kinds of markings they employ (e.g. color patches, lines, or texture elements), and in their reliance on abstraction and stylization.



Perspective painting Orthographic drawing Map

Figure 4: Systems of depiction: perspective painting, orthographic drawing, and map. (Left: Johannes Vermeer, *The Milkmaid*, c.1658; middle: U.S. Patent 150,828, 1874; right: *Middlesex County Atlas*, 2002.)

Maps are a special case of depiction that typically employ (i) orthographic projection of a geographic region from above, (ii) extensive symbolic annotation, (iii) little or no perceptual depth cues (Leong, 1994; Camp, 2018). Meanwhile, three-dimensional icons, including architects' models, sculptures, and gestures, rely on scalar projections from 3D space into 3D space (Schlenker and Lamberton, 2024). Examples of these depictive systems are shown in Figure 5.

classifier construction | architects model | children's toy

Figure 5: Iconicity in three dimensions: narrative construction in ASL, architects model, children's rocking chair. (Left: see Schlenker and Lamberton, 2024; middle: North Curl Curl House, ADAD; right: LappsToys, Etsy

Finally, **diagrams** correspond to the heterogeneous class of 2D iconic representations whose content is *not* viewpoint-based (Giardino and Greenberg, 2015). They include, for example, bar graphs, timelines, Venn diagrams, directed graphs, and Cartesian graphs. Unlike pictures, diagrams are interpreted without dependence on a spatial viewpoint. They employ categorical, topological, and metric structures to directly convey a wide range of logical and quantitative contents. Diagrams almost always include rich symbolic annotations. Some diagram types, like Venn diagrams or directed graphs, are designed to express precise logical content, equivalent to expressions in formal languages (Shin, 1994). See Figure 6 for a sampling of diagram varieties.

Today, the study of iconicity has expanded well beyond visual artifacts to include a wide range of spontaneously generated iconic signs in face-to-face communication. These icons occur in tight coordination with linguistic expressions, and in many cases, are considered part of language itself. Some of the most prominent forms of iconicity in language include:

- **Lexical iconicity** is a feature of words that resemble aspects of their denotations—such as the word *cuckoo* and that bird's characteristic call; it includes, at least, onomatopoeia, ideophones, sound symbolism, and conventionalized sound effects (Dingemanse, 2018).
- **Imitations** and **demonstrations** are uses of the body, hands, and voice to imitate actions—such as a bird call, or a look on someone's face—or to provide instructions—how to perform a tennis serve, for example (Clark and Gerrig, 1990; Davidson, 2015).
- **Iconic gestures** are configurations of the body and hands that are used in parallel with

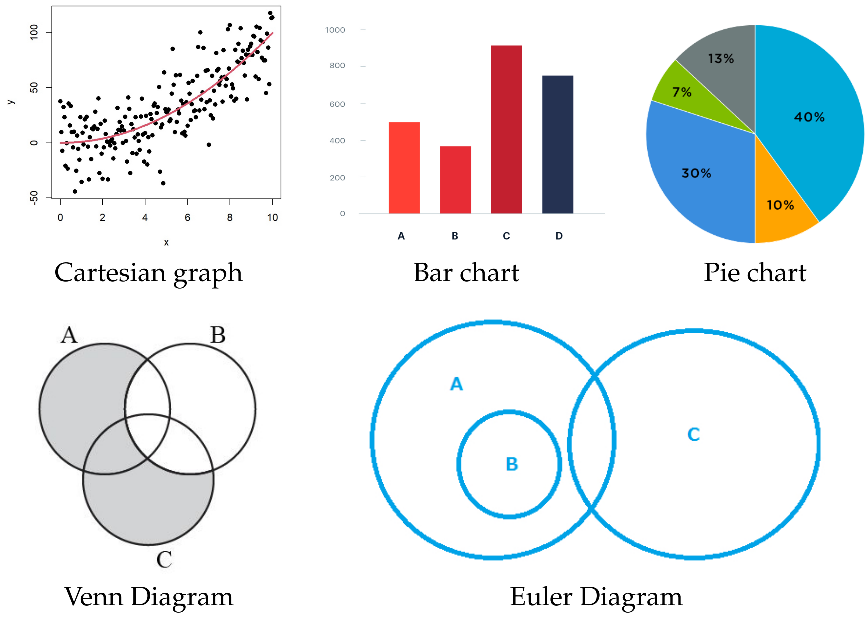


Figure 6: Varieties of diagrams: a small sampling of the many forms of diagram in contemporary use.

speech to depict objects and scenes from the discourse. They may be contrasted emblematic gestures—like the thumb's up sign or middle finger—which are essentially symbolic signs of the hand (McNeill, 1992).

- **Iconic sign language** covers a wide range of phenomena within sign languages in which iconic elements are fused with traditional grammatical forms; they range from iconically modified pronouns to fully map-like **classifier constructions** (Liddell, 2003; Schlenker and Lamberton, 2024).

These cases of face-to-face iconicity are among the oldest forms of iconic communication among humans, and they may even explain the human ability to use iconic artifacts like diagrams, maps, and pictures. They are also one of the few cases where iconic signs are produced spontaneously, without reflection or formal training, making them an essential starting point for cognitive science.

The examples discussed so far have all been forms of public communication. But philosophers and cognitive scientists have also pinpointed a number of potential sites of iconicity in the mind and brain, including the following.

- **Analog magnitude representations** are gauge-like neural systems that employ variations in neural activity to logarithmically encode magnitude variables in the environment. They are often taken to exemplify mental iconicity (Carey, 2009; Beck, 2015).

- **Perceptual representations**, especially in early visual processing, are widely thought to exhibit iconic characteristics, both in their overall representation of space and in the way they encode specific visual features like color and orientation (Clarke, 2022; Burge, 2018; Block, 2023).
- **Iconic memory** and **echoic buffer** are forms of short-term visual and auditory memory which exhibit high-capacity parallel information storage, suggestive of an underlying iconic format (Sperling, 1960; Neisser, 1967).
- **Mental imagery** displays distinctive psychological signatures which seem to mirror the behavior of ordinary pictures (Block, 1983; Tye, 1991; Kosslyn et al., 2006).
- **Topological areas** are regions of the brain in which the spatial distribution of neural activity directly mirrors some external, sensory stimulus; they include retinotopic maps in the visual system, tonotopic maps in the auditory cortex, and brain maps responsible for touch perception and motor control (Wandell et al., 2007).
- **Cognitive maps** are widely attested mental representations of geographic layout that are used to support navigation. While such maps clearly carry spatial content, it remains an open question whether this content is conveyed iconically (Rescorla, 2009).

These examples suggest that researchers are only beginning to scratch the surface on the tremendous variety of iconic forms at work in the human mind, and beyond.

3 Questions, Controversies, New Developments

Semantic properties of iconic representation

What distinguishes iconic from non-iconic representation? In recent decades, there has been a sustained effort to identify the distinguishing features of iconic systems, beyond traditional ideas about resemblance and isomorphism.

Among the most cited features of iconic signs is their conformity with a compositional rule known as the **Parts Principle** (Sober, 1976, p. 122; Fodor, 2008, p. 173). The starting observation is that if you cut a picture into arbitrary parts, each part will still be a picture, and it will depict a part of what the original depicts. Generalizing: a representation R is iconic if and only if for any R' that is part of R, the content of R' is part of the content of R. For instance, in a directed graph, removing arbitrary nodes (and their links) results in a well-formed directed graph, which represents a subset (a *part*) of the relations represented by the original. The same does not hold for sentences; given a sentence like the one in Figure 7, removing arbitrary parts might result in the string "rains, use an" which does not have any linguistic content, much less a content that is a part of the original proposition.

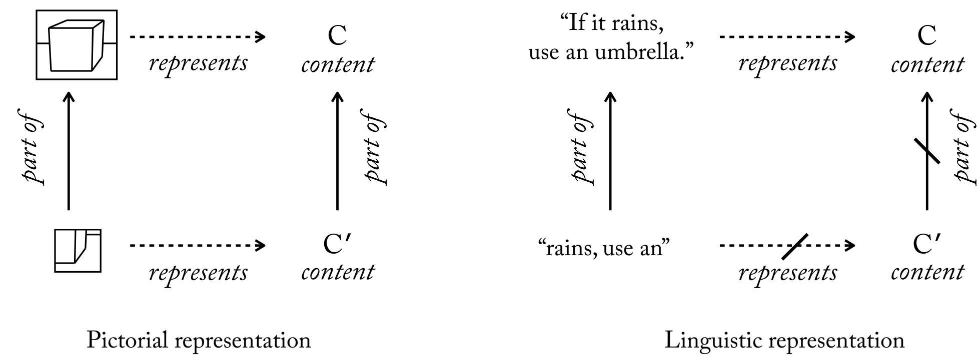
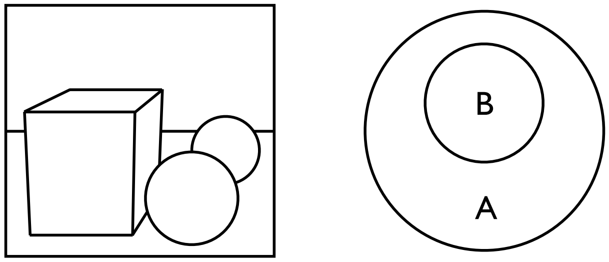


Figure 7: The Parts Principle: if P represents C, then parts of P represent parts of C. Pictures but not sentences obey the parts principle.

The empirical adequacy of the Parts Principle has been extensively debated. Critics have noted that it fails to extend to first-order icons, since they lack parts (Block, 2023, p. 225), that it relies on a vague notion of parthood (Kulvicki, 2015, pp. 176–179; Burge, 2018, pp. 86-91), and that it seems to preclude hierarchical iconic representations in perception. Nevertheless, it reflects the fundamental organization of many complex icons, which combine a flat, non-hierarchical syntax with a correspondingly uniform rule of interpretation.

Complex icons also exhibit various forms of **semantic holism**: they express contents which bind units of information together, whereas linguistic representation is modular and discrete (Dretske, 1981, ch. 6; Shin, 1994, ch. 6; Camp, 2018; Green and Quilty-Dunn, 2021). For example, if a drawing represents the shape of an object, it must also make a commitment about the location of that object in visual space. Likewise, if an Euler diagram represents a set A as overlapping B, it also necessarily makes a commitment about whether A is a subset, superset, identical to, or disjoint with B. The same is not true for sentences, of course, which can express each of these relations atomistically and independently (see Figure 8).



(i) Some Bs are As.

(ii) All Bs are As.

(iii) All Bs are As and
some As are not Bs.

Figure 8: Semantic holism. Pictures and diagrams (left) exhibit semantic holism: logically distinct propositions are necessarily expressed together. Sentences (right) can always express logically distinct propositions independently.

In many cases, holism gives rise to distinctive patterns of inference. Consider the result of sequentially adding premises to each of two complex representations, as shown in Figure 9—on one hand, a traditional logical proof, on the other, an iconic representation of a timeline. Suppose one adds the information contained in the premises "A<B" and "B<C" to each. In the linguistic case, a further principle of transitivity must be added explicitly in order to infer "A<C". But in the iconic case, the same conclusion seems to be ushered in automatically, an effect known as a **free ride** (Shimojima, 2001). Free rides arise when the structural rules of an iconic system mirror the laws of the domain it represents, so that manipulating the sign correctly guarantees a valid conclusion. In this way, iconic representations have the unique power of introducing constraints on reasoning without need for explicit encoding. (Shimojima, 2015)

Linguistic inference

1. B is before C.

2. A is before B.

3. Relation *before* is transitive.

Therefore:

A is before C.

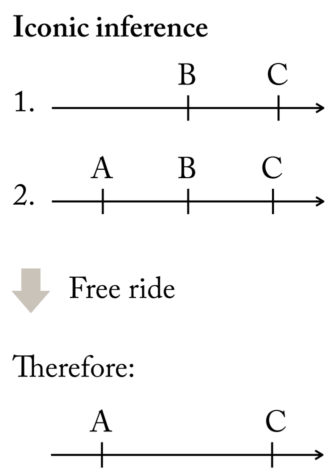
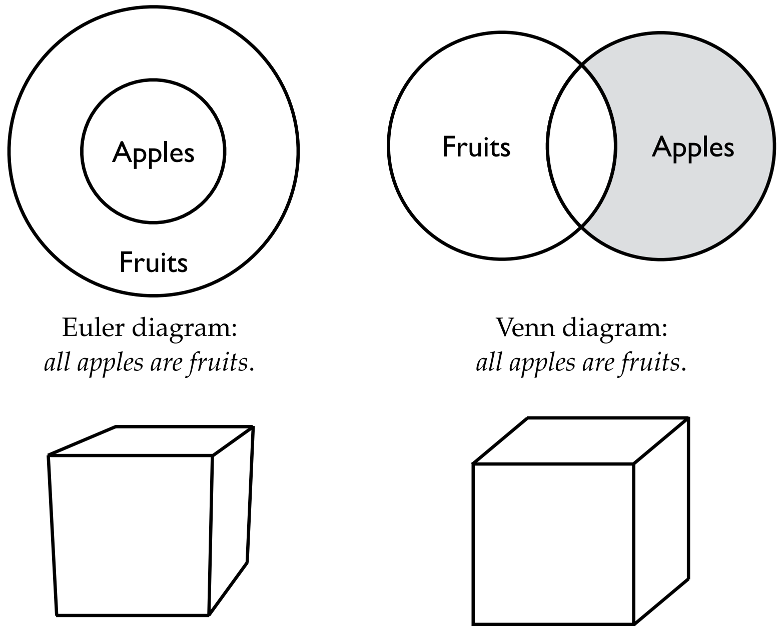


Figure 9: Free rides in iconic inference. Whereas linguistic inference requires an explicit statement of transitivity (Premise 3), this assumption appears to come *for free* in an iconic format.

There is little consensus about which, if any, of these semantic properties defines iconicity, or whether iconic representation is best defined as a cluster of such features. Some have questioned whether iconicity constitutes a unified category at all (Goodman, 1968; Camp, 2018; Greenberg, 2023). Others have suggested instead that the various signatures of iconicity derive from a common root, pointing to the underlying **semantic rules** that map sign-forms to contents (Lee et al., 2023; Greenberg, 2023). This perspective shifts the focus from *what* iconic representations do, to *how* iconic representations work. It remains an open question whether a unique iconic mechanism can explain the variety of expressive phenomena surveyed here.

Convention and iconic representation

Historically, it was often assumed that iconic representation was opposed with representation by convention (Peirce, 1998). Today, however, most scholars reject this simple opposition (Eco, 1976; Bordwell, 2008; Cumming et al., 2017). After all, drawing systems and diagram systems seem to be used in culturally local, socially determined ways that are characteristic of convention. The point is dramatized by considering iconic systems that use the same elements in different ways. For example, overlapping circles have different set-theoretic interpretations in Euler and Venn diagrams; likewise, converging lines on the picture plane have different geometrical interpretations in parallel and perspective projection (Giardino and Greenberg, 2015). Just as words have no intrinsic meaning without the support of a conventional language, circles and lines have no meaning in a diagram or picture without an accompanying iconic convention.



Euler diagram:
all apples are fruits.

Venn diagram:
all apples are fruits.

Linear perspective: cube.

Parallel projection: cube.

Figure 10: Iconic conventions. Above: Euler and Venn diagram representations of the proposition *all apples are fruits*. Below: linear perspective and parallel projection depictions of a cube. (Images reproduced from Giardino and Greenberg, 2015.)

But are iconic conventions really possible, if conventions are arbitrary? According to one influential analysis, a **convention** is a repeatable solution to a coordination game in which more than one solution is available (Lewis, 1969). Driving on the right side of the road is such a solution, since there is a repeatable problem of coordination with other drivers, and there is an obvious alternative to drive on the left. On this view, conventions do require alternatives, but the choice between them need not be arbitrary. Indeed, it seems that some conventions are more **natural** than others, meaning they are more readily available and easier to use for typical subjects (Bordwell, 2008; Cumming et al., 2017). If iconic systems are natural conventions, this would explain why interlocutors with no common language typically revert to gesture or depiction; and why, in general, iconic systems can often be readily understood by participants with little shared common ground.

Recent research in **experimental semiotics** has shown that, in communication games without a shared language, participants initially rely on iconic strategies; but with repetition, their signs become increasingly stylized and arbitrary, suggesting that communication naturally progresses through stages of iconicity and conventionalization (Garrod et al., 2007; Hawkins et al., 2023).

Rudimentary iconic representations appear to be immediately available to naive interlocutors; non-iconic symbols are more efficient to use, but require greater coordination to establish.

Iconic representation in perception

In the philosophy of psychology, there is an ongoing debate about the iconic nature of perception, especially vision (Beck, 2018). A number of scholars have defended the view that perception is *fully* iconic—that is, all perceptual representations, at all levels of organization and processing, are iconic (Burge, 2018; Block, 2023; Clarke, 2022), from low-level spatial features to high-level object representations. By contrast, others have defended **perceptual pluralism**, the view that some perceptual representations are iconic, while others are symbolic (Quilty-Dunn, 2020; Green and Quilty-Dunn, 2021; Green, 2023). All parties agree that the representations in the early stages of visual processing are likely to be iconic; but there is debate about the proper evidence for this claim, and the status of late-stage vision. Part of what is at stake here is whether the border between perception and cognition can itself be defined by the distinction between iconic and language-like representation (Burge, 2018; Block, 2023; Green, 2023).

The broader debate is reflected in a controversy about **object files**, hypothesized structures in late-stage vision that track a limited roster of visual objects. Some argue that object files are not iconic, citing experimental evidence of atomistic logical structure (Green and Quilty-Dunn, 2021), while defenders of the thoroughly iconic view have questioned this interpretation (Burge, 2018; Block, 2023).

A second subject of debate is the significance of **retinotopy**, the topological alignment between regions of the brain and regions of the retina that results in picture-like patterns of activity in the visual cortex. The question is whether retinotopy in the visual cortex implies the presence of picture-like iconic representations in the brain. Advocates point to the rich spatial correspondences between retinotopic areas, conscious visual experience, and spatial behavior (Kosslyn et al., 2006; Burge, 2018), as well as the role of retinotopic areas in spatial computing. Skeptics have argued that the implementation of neural circuits is not itself relevant to questions of format, which should reflect purely functional aspects of representation (Pylyshyn, 2003).

4 Broader connections

AI and deep learning

The explosive rise of artificial intelligence during the 2020s has already transformed society's engagement with pictures. Neural network models have narrowed the gap between description and visualization, making powerful tools for understanding and generating images widely available. Vision models trained on photographs can classify drawings and sketches with human-like performance (Fan et al., 2018), and specialized models now extract content from charts and graphs.

Of special interest to cognitive science are the deep representations at the hearts of computer vision models. For example, vector representations, a commonly used data structure, are long sequences of numerals that represent points in high-dimensional feature spaces. They may encode the information carried by a sentence, picture, or entire discourse. Researchers today have a limited understanding of the content carried by vector representations; and it is natural to ask whether the operative semantic principles are more nearly iconic or symbolic, or if they reflect a genuinely alternative form of distributed representation (Haugeland, 1991).

Computer vision models typically operate over image-like value arrays, known as **feature maps**. In a **convolutional neural network** (CNN) architecture, an input image is processed through a hierarchical sequence of feature maps which gradually decrease in spatial resolution and increase in abstract depth (Fukushima, 1980). CNNs have been shown to mirror the core hierarchical functions of the human visual system. The transformation from early picture-like layers to later abstract layers seems to mark a key computational role for iconic representation that researchers are still coming to understand.

Super-linguistics

Over the 20th century, **formal semantics** made linguistic meaning amenable to scientific study, while iconic representations were often considered un-formalizable. Today, the emerging field of **super-linguistics** aims in part to extend the tools of generative linguistics to iconic signs (Patel-Grosz et al., 2023).

Iconic phenomena that are part of natural language, or accompany it, have been a focal point of this work. In particular, iconicity in sign language has recently begun to be analyzed from the perspective of formal semantics. For example, **loci** are locations in sign space that are used to track objects under discussion, but can iconically represent properties like height, importance, or part-whole relations (Schlenker and Lamberton, 2024). These iconic elements have been successfully modeled with analytical tools inspired in part by picture and diagram semantics. Likewise, **classifier constructions** are narrative sequences which smoothly integrate conventionalized handshapes with map-like scene depictions. Attempts to model classifier constructions have drawn from the semantics for demonstratives (Davidson, 2015) and the semantics of pictures (Schlenker and Lamberton, 2024), but work remains to capture their dynamic and three-dimensional structure.

Parallel work on gesture has focused on two related semantic problems. First, how do iconic gestures that accompany speech contribute to the content of the discourse as a whole? For example, do gestures comment on, illustrate, or work independently of the main text? Second, how do these brief sketches with the hands and body iconically represent objects, properties, and events? Progress has been made in both areas by extending insights from discourse semantics, pictorial semantics, and theories of presupposition (Lascarides and Stone, 2009; Lücking et al., 2024).

In co-evolution with the semantic study of iconicity in sign language and gesture, a wave of recent scholarship has adapted methods from linguistics to the study of pictures, film, and comics. A key insight here is that the contents of visual and other iconic representations can be modeled using the same formal tools at work in linguistic semantics (Abusch, 2012; Kulvicki, 2020). For example, **projection semantics** offers formal semantics for pictures that maps pictorial geometry to informational content (Greenberg, 2021). Building on these foundations, researchers have developed formal accounts of visual narrative in comics and film (Maier and Bimpikou, 2019; Cumming et al., 2017), and extended semantic analysis to pictorial speech acts (Esipova, 2021).

The success of super-linguistics highlights the reach of linguistic methods beyond language—and marks a decisive return to the original ambitions of semiotics.

Multi-modality

Most human communication is **multi-modal**, meaning that it combines elements from distinct representational systems. Familiar examples include the words and symbols on road maps, newspaper articles with images and captions, and the graphical interfaces on smart phones. Face-to-face communication, the most ancient form of exchange, involves a precise coordination of speech, iconic gesture, and facial expressions. Meanwhile, the production of rich, multi-modal communication is a still unattained goal for current AI models.

To interpret a multi-modal expression requires competence with the uni-modal systems of representation associated with each part; but in addition, it demands a more general competence with how to combine these parts into a meaningful whole. Yet these combinations don't seem to follow the pattern of linguistic compositionality, which is based on the systematic combination of logical forms. Instead, multi-modal composition involves the integration of iconic and symbolic structures together.

Researchers have explored a number of distinct approaches to the iconic/symbolic interface. In some cases, linguistic content contributes to explicit foreground assertions, while iconic content fills in background assumptions. In others, iconic and linguistic signs are linked by cross-referencing relations that allow them to refer to the same objects (Schlenker and Lamberton, 2024; Maier, 2025), or iconic modulation of standard lexical items (Patel-Grosz et al., 2023). In the case of maps, linguistic labels are often viewed as modulating the iconic meaning of the map—for example, a written label like "Lake Michigan" combines symbolic naming with the spatial depiction of the surrounding region (Leong, 1994; Camp, 2007). In the case of prohibition signs, a pragmatic mechanism has been postulated which transforms iconic meanings into conceptual, symbolically accessible ones (Esipova, 2021). Meanwhile, researchers in AI have sought to capture statistical dependencies between pixel distribution and the words around them, summarized as multi-modal vector representations. A final, especially prominent approach treats multi-modal expressions as **discourse**, extending the theory of discourse coherence relations to the links between iconic and symbolic elements: in gesture (Lascarides and Stone, 2009), film (Cumming et al., 2017), and comics (McCloud, 1994).

Future inquiry will have to address why multi-modal representation is so natural for human communicators; rather than passing through a uni-modal stage, a blend of iconic and symbolic representation appears to be built into human cognition at a fundamental level.

5 Further reading

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