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Abstract

The London Underground Diagram (LUD) is a cognitive artifact and a well-known example of representational efficiency, having been copied by urban transportation systems worldwide. Here we describe the design of the LUD as an example of cognitive niche construction happening through iconic meaning of a problem space. We argue that the LUD's meaning is grounded on the offer of opportunities for action through diagrammaticity. Our examination suggest that iconicity is at the core the cognitive niche construction.

Keywords: Cognitive niche; Iconicity; Diagrams; Cognitive semiotics

Introduction

The concept of cognitive niche, an extension of the concept of ecological niche, stresses the environmental offer of opportunities for thought as a major process in cognitive development. The construction of cognitive niches has been related to enhancement of problem solving activities (Clark, 2008), the evolution of culture (Pinker, 2008; Laland & O'Brien, 2011) and the birth of language (Bickerton, 2009). At the core of these research endeavors is the notion of meaning, which binds together cognitive niche construction, cultural evolution, problem solving and language. However, there hasn't been more attentive examinations on how cognitive niche construction is grounded on meaning and vice-versa.

The London Underground Diagram (LUD) is a well-known example of representational efficiency, having been copied by urban transportation systems worldwide. Here we describe the design of the LUD as an example of cognitive niche construction happening through iconic meaning of a problem space. Our argumentation has the following structure: (i) we briefly introduce the notions of sign and icon, following C.S. Peirce's pragmatic philosophy of signs; (ii) we briefly describe the design innovations that characterize the LUD in comparison to older maps of the Underground system; (iii) we claim that these design innovations make the LUD a more specialized icon of a specific problem space; (iv) we claim that such iconic meaning of a problem space characterizes the LUD's role in cognitive niche construction.

Signs and icons

Charles Sanders Peirce, founder of the modern philosophy of signs, defined semiotics as a kind of logic: a science of the essential and fundamental nature of all possible varieties of meaning processes (*semiosis*). Peircean approach of semiosis is related to formal attempts to describe cognitive processes in general. His framework provides: (i) a pragmatic model of semiosis and a conception of mind as a sign-interpretation process (see Fetzer, 1988; Ransdell, 1977); (ii) a list of fundamental varieties of representations based on a theory of logical categories (Savan 1987/88).

According to Peirce's model, any description of semiosis involves a relational complex constituted by three terms irreducibly connected -- Sign, Object and Interpretant (S-O-I). The irreducibility indicates a logical property of this complex: the sign process must be regarded as associated to the interpretant, as an ongoing process of interpretation (Hausman, 1993, p. 9; Colapietro, 1989), and it is not decomposable into any simpler relation (see EP 2:391).

There are three fundamental kinds of signs underlying meaning processes – icons, indexes, and symbols. Respectively, a sign may be analogous to its object, spatio-temporally connected to it, or might represent it by means of a law, rule or norm. These classes correspond to relations of similarity, contiguity, and law between sign and object (see Table 1). Icons are signs which stand for their objects through similarity or resemblance, irrespective of any spatio-temporal physical correlation that S may have with an existent O. If a determinative relation of the sign (S) by the object (O) is a relation of analogy, that is, if S is a sign of O in virtue of a certain quality that S and O share, then S is an icon of O. S and O are related due to the identity of some aspect they share. Icons are very dependent on the material, form and structure of which they are made – "An Icon is a sign which refers to the Object that it denotes merely by virtue of characters of its own, and which it possesses, just the same, whether any such Object actually exists or not" (CP 2.247). In this sense, an Icon logically determines its Object, i.e. S-O in S-O-I is dependent on the intrinsic properties of S.

In contrast, if S is a sign of O by reason of "a direct physical connection" (CP 1.372) between them, S is said to be an index of O. In that case, S is really determined by O, in such a way that both must exist as events -- "An Index is a sign which refers to the Object that it denotes by virtue of

being really affected by that Object" (CP 2.248). The notion of spatio-temporal co-variation is the most characteristic property of indexical processes. The examples range from a pronoun demonstrative or relative, which "forces the attention to the particular object intended without describing it" (CP 1.369), to physical symptoms of diseases, photographs, weathercocks, thermometers. Finally, in a symbol, the relation between S and O is logically dependent on the third term, I. In a symbolic relation, the interpretant stands for 'the object through the sign' by a determinative relation of law, rule or convention (CP 2.276).

Table 1. The fundamental types of signs underlying meaning processes – icons, indexes, and symbols. They are characterized in terms of relative dependence of sign-object-interpretant (S-O-I) components in triadic relation.

Type of sign	S-O relation	S-O-I dependence
icon	"similarity"	dependent on intrinsic properties of S
index	"contiguity"	dependent on S-O spatio-temporal co-variation
symbol	"law"	S-O dependent on I mediation

As soon as an icon can be considered as consisting of interrelated parts, and since these relations are subject to experimental manipulation governed by laws, we are working with diagrams. The diagram, therefore, is an icon of relations (NEM 4:316; Johansen, 1993, p.99). The object of the diagram is always a relation, and the related parts of the diagram represent the relations that constitute the object represented.

The London Underground Diagram

The design of the London Underground Diagram (LUD) is a well-known example of representational efficiency. Present in virtually every major city in the world, it has established an international paradigm on how to perform simple decision-making tasks regarding networks of stations and lines. The original version of the LUD was created by the Henry C. (Harry) Beck in 1933. Beck's design was based upon electrical circuit diagrams, which omit or falsify the relative physical position of wires in order to convey information about connectivity. Beck saw a similarity with the underground railway network in that it was possible to ignore the geographical information altogether and remove some of the sources of confusion in the previous, more literal maps.

Beck's initial sketch was transformed into a properly labeled and color-coded diagram where he compressed the outlying portions of lines. The central area of the network appears to be viewed through a convex lens so as to enlarge its scale, route lines are simplified in verticals, horizontals and diagonals (45°) and the distance between stations has been evened (Garland, 1994).

In later versions of the London Underground Diagram based on the last of Beck's diagrams (published in 1959), his successors retained the essential structure from the original: octagonal grid and colored lines meeting at angles of 90° or 45°; stations arranged to show the position of each one to the next instead of the real geographic distance between them; the presence of the simplified River Thames along the bottom of the diagram helping the notion of position and scale; non-interchange stations represented by ticks and interchange stations represented sometimes by rings sometimes by diamonds (Garland, 1994). Graphical changes such as changing the color of the lines and the fonts used in the names of the stations in order to improve the grasping of information by the users and reduce their possibility of confusion were made, also to accommodate the expansion of the system. As a result of the adaptations and modifications made by Beck and his successors, we have the diagram as we know it today (see Figure 1).

What does the LUD signify?

Previously to the LUD, maps of the London Underground System adhered to geographically more accurate representations of the lines and station locations. While both the LUD and a geographically accurate map convey information about stations, connections between stations and connections between lines, only the map convey reliable information about geographic location of stations, distance between stations, length of lines and specific directions and changes of directions of lines. We can say that there is more information to be discovered about the Underground System in a geographically accurate map than in the LUD.

To characterize the LUD as a sign whose object is the London Underground System, while correct, doesn't reveal much about the functional role it plays. Beck's design has selected, between a multitude of information possible to be communicated by a map or diagram, just what was required for a user of the Underground system to solve the specific problem of navigating the system. His design communicates something not only about "the Underground System" in general as a "thing" or "substance", but about a problem space typical of the users of the system, and partly inherent to the system itself.

 The representational features of the LUD are an icon of a formal structure of this problem space. This formal structure comprises an initial state (the user's current station), a final state (user's goal station), intermediate states (the intermediate stations and their structure of connectivity) as well as a set of rules for moving between states (the user needs to move along a line, can only embark or disembark on stations and can only change between specified lines on interchange stations). More specifically, the iconicity between the LUD and the formal structure is not because of similarity of superficial qualities, but because both share a structure of relations between its parts: the connectivity between stations (ticks and diamonds) and tube lines (graphical color-coded lines) in the LUD is analogous to the connectivity between problem states in the problem space. Thus, the reltion between the LUD and the problem space of the Underground users is based on diagrammaticity.

Figure 1: The London Underground Diagram as we know it today.

The LUD constructs the cognitive niche

For Laland & O'Brien (2011, pp. 192-193) niche construction "should be thought of as the dynamical products of a two-way process involving organisms both responding to 'problems' posed by their environments and solving some of those problems, as well as setting themselves some new problems by changing their environments through niche construction". Similarly, for Clark (2008, pp. 62-63), cognitive niche construction is a process of transformation of problem spaces by building physical structures that, combined with appropriate culturally transmitted practices, enhances problem solving or even make possible new forms of thought.

Taking into account the characterization of niche construction as related to transformation of problem spaces, and our claim that the LUD is an icon of a problem space, how can we further characterize the role of the LUD, with its diagrammatic meaning, in a process of niche construction? In the following we argue that LUD's diagrammatic meaning of opportunities for actions *is* the LUD's role in niche construction, arguing that meaning and niche construction cannot be dissociated.

Take someone who is in Victoria station and needs to go to Marylebone station. She consults the LUD, performing S-O-I: the LUD (S) represents a problem space (O), so that the blobs and color-coded lines stand for her as possibilities for action (I) — "Marylebone is in the brown line, I can access the brown line in Oxford Circus, or maybe in Baker Street, after transfering to the grey line in Green Park". She thinks about displacement in terms of connectivity — and not, say, in terms of distance —, not because she has taken some time to think about the best way to think about urban dislocation, but because the LUD makes it almost impossible to think otherwise: she is not using the diagram as merely input for abstract processing of information about the underground system, but rather making a decision based on visual manipulation of the diagram itself: even if the underground system didn't exist in reality, the diagrammaticity in the LUD would still afford similar decisions regarding the options to go from blob 'A' to blob 'B'. That is, in S-O-I, the S-O relationship is dependent on internal relations of S (i.e., diagrammaticity). This diagrammaticity of the LUD when coupled to a context of action and decision making, offers opportunities for action and shapes decision making.

To solve a problem using the LUD involves assessing the potential actions offered and choosing one. Several factors, strategies and preferences might be involved in the choice: being late, having heard that someone was robbed in one particular station, trying to make the least possible connections, trying to pass through the least number of stations, avoiding a certain crowded line etc. Regardless of the motives, if the choices are informed mainly by the manipulation of the LUD, they can only happen in terms of the opportuni-

ties for action that the LUD embeds. To solve a problem using the LUD corresponds to actualizing in experience one of the many potential actions offered by the LUD.

Some of the strategies, needs and preferences of users may not be supported by the design choices of the LUD: trying to figure out which station is closer to a particular street, for example. The set of potentialities for action that a representation designed specifically for solving problems of navigation in the underground system embeds is only one between many other possible sets that might be derived from the system: that of a mechanic trying to locate a particular electrical fault in the system, for example, or that of a rat which lives in the underground. The set of potentialities that the LUD offers is a crucial part of any description or characterization of how thousands of commuters and tourists (and not mechanics, and not rats), relate to the London Underground System everyday. This set opportunities for action is a part of the cognitive niche of Londoners, and it is founded on diagrammatic meaning. Meaning, in this case, is not a matter of a certain type of reference of a thing to a mind, but is inextricably connected to the niche itself, i.e., the niche is the context required for meaning to develop.

Conclusion

How is meaning grounded on cognitive niche construction and vice versa?

According to Peirce's pragmatism, signs are action-oriented, context-dependent processes and entities – they are determined by the fact that they figure in a process in which what is selected as relevant is grounded on the needs of agents acting locally in a cognitive niche. Meaning works as a constraining factor of possible patterns of problem solving behavior.

In relation to other types of underground maps, the LUD does not introduce a distinct kind of semiotic process, but specializes the semiotic process to signify mainly in terms of connectivity. In this sense, the LUD serves as an example of meaning as an action-oriented process.

The utilization of the LUD by an Underground user can be understood as a meaning process S-O-I in which O is a problem space. As this is an iconic process, O is dependent of the intrinsic qualities of S, so that changes in S generate transformations in O. Beck's design innovations (changes in S) transform the problem space (O), participating in cognitive niche construction. In this sense, iconic meaning (more than indexicality or symbolicity) is at the core of cognitive niche construction. This approach suggests a new philosophical treatment of the relation between problem space, cognitive niche construction and meaning processes.

Acknowledgments

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