Dicent Symbols and Proto-propositions in Biological Mimicry

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(…) A Dicent Symbol, or ordinary Proposition, is a sign connected with its object by an association of general ideas, and acting like a Rhematic Symbol, except that its intended interpretant represents the Dicent Symbol as being, in respect to what it signifies, really affected by its Object, so that the existence or law which it calls to mind must be actually connected with the indicated Object. Thus, the intended Interpretant looks upon the Dicent Symbol as a Dicent Indexical Legisign; and if it be true, it does partake of this nature, although this does not represent its whole nature. Like the Rhematic Symbol, it is necessarily a Legisign. Like the Dicent Sinsign it is composite inasmuch as it necessarily involves a Rhematic Symbol (and thus is for its Interpretant an Iconic Legisign) to express its information and a Rhematic Indexical Legisign to indicate the subject of that information. But its Syntax of these is significant. The Replica of the Dicent Symbol is a Dicent Sinsign of a peculiar kind. This is easily seen to be true when the information the Dicent Symbol conveys is of actual fact. When that information is of a real law, it is not true in the same fullness. For a Dicent Sinsign cannot convey information of law. It is, therefore, true of the Replica of such a Dicent Symbol only in so far as the law has its being in instances. (CP 2.262)

Introduction

Sign-mediated processes show a remarkable variety. The construction of appropriate typologies of these processes is a requisite for a deeper and more refined understanding of animal communication. In an attempt to advance in the understanding of sign-mediated, i.e., semiotic processes, Peirce proposed several typologies, with different degrees of refinement and diverse relationships to one another. A basic

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typology in his framework differentiates between iconic, indexical, and symbolic processes. An attempt to classify the signs mediating mating, courtship, competition, and predation in fireflies in accordance with the Peircean framework shows, however, that this basic typology is not sufficient and, moreover, leads to unexpected findings with regard to firefly communication, as we will see below. The fact that we need to go beyond this basic typology is in itself telling.

Peirce developed several classifications of signs based on different trichotomies (see MS 540; L 463: 132–6). One of them concerns specifically the 10-fold classification as described in the 1903 Syllabus (MS 540, EP 2: 289–299), while the others deal with the deep structure of Peirce's various trichotomic classifications—six trichotomies (28 classes), and ten trichotomies (66 classes) (see Farias and Queiroz 2000, 2003; Freadman 2001, 2004). This implies a deep level of detail in the description of the relations observed in semiosis, as a process involving the interaction of sign, object, and interpretant.

Here we are especially interested in how Peirce's 10-fold classification of signs can contribute to the construction of models that may serve as tools for the investigation of biological mimicry. As a corollary to our analysis of firefly signaling (El-Hani et al. 2010), we analyze the capacity of producing propositions (i.e., dicent symbols) as a general requisite for a semiotic system to act as a mimic. We intend to show that Peirce's mature theory of signs brings an important contribution to the building of a general semiotic theory of mimicry, since it is quite helpful in addressing semantic and pragmatic aspects of biological information. As is well known, the semiotic processes involved in biological mimicry most often do not result from learning processes taking place in the individual semiotic system, but from the fine-tuning of inherited capacities by natural selection among variants over thousands or millions of generations. Still, the concrete sign exchange takes place within the lifetime of a single individual, and those signals, indicating and describing at the same time, should be conceived of as dicent symbols or dicisigns. This calls for an investigation of the Peircean notion of the dicisign, which is a generalization of the notion of proposition. A key feature of this Peircean notion is that it liberates assertions from the confines of language and points to their appearance also in pictures, gestures, mixed media, etc. That is, it generalizes propositions from being a human privilege so as to also embrace simpler dicisigns found in the biological realm.

Some Basics of Peirce's Model of Sign-Action

Peirce's semiotics is defined as the doctrine of the essential and fundamental nature of all possible varieties of sign-mediated processes. From this perspective, we can speak of such processes at several biological levels of organization, and, certainly, a treatment of animal communication from a semiotic perspective is worthwhile. Living beings are generally treated, according to this perspective, as semiotic systems, i.e., systems that produce, communicate, and interpret signs. No anthropomorphism is necessarily involved in this approach, and the presence of consciousness needs

not to be assumed in talking about signs. We can think of semiotic modeling as an attempt to build general, abstract models of sign-mediated processes, which select among the several features involved in such processes some which are taken to be fundamental elements to be modeled in a general manner, and some which are regarded as peculiar elements of some kinds of sign processes.

In this model, we find several clues to understand how signs act. The model says that any sign is something that stands for something else, its object, in such a way that it ends up producing a third relational entity/process, an interpretant, which is the effect a sign produces on an interpreter (in our case, an animal). In many sign-mediated processes, sign interpretation results in a new sign within the interpreter, which refers to the same object to which the former sign refers, forming a chain of inferences, or ultimately to result in an action, which can lead to the termination of the process.

A sign is also pragmatically defined as a medium for the communication to the interpretant of a form embodied in the object, so as to constrain, in general, the interpreter's behavior (Peirce MS 793:1-3. See EP 2.544, n.22, for a slightly different version).[1]

The object of sign transmission is a habit (a regularity, or a 'pattern of constraints') embodied as a constraining factor of interpretative behavior—a logically 'would be' response. The form is something that is embodied in the object as a 'regularity', a 'habit', a 'rule of action', or a 'disposition'. Form is defined as having the 'being of predicate' (EP 2.544) and it is also pragmatically formulated as a 'conditional proposition' stating that certain things would happen under specific circumstances (EP 2.388). For Peirce, it is nothing like a 'thing' (De Tienne 2003), but something that is embodied in the object (EP 2.544, n. 22) as a habit, a 'rule of action' (CP 5.397, CP 2.643), a 'disposition' (CP 5.495, CP 2.170), a 'real potential' (EP 2.388) or, simply, a 'permanence of some relation' (CP 1.415).

Fundamental Classes of Signs

As it is well-known, sign-mediated processes show a notable variety. According to Peirce, there are three fundamental kinds of signs underlying meaning processes—icons, indexes, and symbols (CP 2.275). Respectively, a sign may be analogous to its object, spatiotemporally connected to it, or might represent it by means of a law, rule or norm. These classes correspond, then, to relations of similarity, contiguity, and law between sign and object.

Icons are signs that stand for their objects through similarity or resemblance, no matter if they show any spatiotemporal physical correlation with an existent object (CP 2.276). In this case, a sign refers to an object in virtue of a certain quality that sign and object share. When the interpreting system receives an effect of the sign (i.e., when an interpretant takes place within it or when it acts due to the detection

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[1] See pages 91–92 of this volume for full quotation.

of the sign), this is due to the communication of a quality of the object to the system through the sign. An icon can refer to an object independently of the spatiotemporal presence of the latter because it denotes the object merely by virtue of characters of its own, and which it possesses no matter if the object is present or not, and, in fact, no matter if the object actually exists or not. Icons play a central role in sensory tasks since they are associated with the qualities of objects. Thus, they are present in the sensorial recognition of external stimuli of any modality. Sebeok (1989) called attention to the fact that iconic signs are found throughout the phylogenetic series, in all sensory modalities, and, furthermore, that iconicity is crucially involved in the phenomenon of mimicry. Through a sign-mediated process with an iconic nature, an animal can modulate the behavior of another animal by communicating through the sign a certain quality shared with an object.

Indices are signs that refer to an object due to a direct physical connection between them. Since in this case the sign should be determined by the object, for instance, through a causal relationship, both must exist as actual events. Thus, in order to have actual effects, icons must be supported by indices. Accordingly, spatiotemporal covariation is the most characteristic property of indexical processes. For instance, if we see an English pointer pointing out the location of a bird, we can analyze the pointing paw as an indexical sign of the bird, its object. This sign has an effect on the human hunter, modulating his behavior so that he looks for the bird, due to the correlation in space and time between the sign—the pointing paw—and the object—the bird. Notice that in this case the sign will misinform the interpreter, the human hunter, if it shows no spatiotemporal correlation with its object. Icons, in turn, do not misinform when the object is not present in the same spatiotemporal frame. But notice that icons, in order to be efficient signs, must appear in connection with indices and their physical pointing to the object of the sign; if this is not the case, icons remain vague possibilities. When associated with indices, however, icons may be part of a process leading the interpreter to be misinformed about an object.

Finally, symbols are signs that are related to their object through a determinative relation of law, habit, or convention. A symbol becomes a sign of some object merely or mainly by the fact that it is used and understood as such, due to some of the kind of relations mentioned above. When we are speaking about the emergence of a symbol, the community of sign-users has a crucial role in establishing the conventions, habits, or laws on which the sign-object relationship is based. Furthermore, differently from indices, symbols can refer to objects not present in the same spatiotemporal frame, and, moreover, they can refer to abstract objects, such as classes or types of entities/processes. It is not necessary, however, that the sign-users have any awareness of the nature of the symbolic relation, or, else, that this relation emerges through sign use and learning during the lifetime of individual organisms. Symbol-mediated processes can emerge throughout phylogenetic time as a result of selective processes operating on a population.

Symbols can be found in non-human animals, such as African vervet monkeys (*Chlorocebus aethiops*, MAMMALIA: PRIMATES), whose alarm-call system is a particularly well-known case of vocal communication in non human primates

(see Ribeiro et al. 2007; Queiroz 2003; Queiroz and Ribeiro 2002). The object of the sign, in the case of the vervet monkeys alarm-call system, is not an object-token but rather a class of objects, i.e., an object-type and, therefore, does not need to exist as a singular event only. This is yet another feature expected in communication by means of symbols. We can analyze the semiotic processes involved in this alarm-call system as involving signs that communicate to (i.e., have an effect on) the interpreting animal a lawful relationship between kinds of calls (signs) and kinds of objects (predators). It allows, thus, the emitter of the call to repeatedly modulate the behavior of its conspecifics in the same, general way so that it is more likely that they successfully avoid a potential predator.

Icons, indices, and symbols are differentiated by Peirce based on how the sign relates to its object, which may be defined, in turn, as the item to which the interpretants are related by the mediation of sign. In an attempt to advance in classifying semiotic processes, Peirce proposed several typologies, with different degrees of refinement. Around 1903, he developed a division into ten classes. According to this typology, symbols can be further analyzed in three subclasses.

The Extended Theory of Signs—Ten Classes of Signs

Impelled by discoveries in different domains (existential graphs, phenomenology, pragmatism), Peirce developed several classifications of signs based on several trichotomies (see MS 540; L 463:132-60; CP 2.233-72 and 8.342-76; EP 2:289-99 and 478-91; Lieb 1977, pp. 80–85).[2] The consequence is an enormous accuracy concerning the relations observed within S-O-I, including the differentiations between Immediate and Dynamical Object, and between Immediate, Dynamical, and Final Interpretant, and the conception of 10 trichotomies, resulting by combination in 66 classes of signs. The trichotomies are aspects according to which the semiosis can be observed and can be translated into questions (cf. Houser 1991). In order to understand the design of the ten classes of signs based on the first three trichotomies, three questions should be formulated: (i) "What is the relation of the Sign with itself?" (1st trichotomy); (ii) "What is the relation between the Sign and its Object?" (2nd trichotomy); (iii) "What is the relation between the Sign and its Object for its Interpretant?" (3rd trichotomy). Following a suggestion given by Rescher (1996, p. 36), we can understand these questions as "oriented problems" about semiosis. For each question, there are three kinds of relation as answers. As an example, for the first trichotomy we have a "monadic relation answer." In this case, this relation

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[2] For an introduction to Peirce's extended classifications of signs, see Savan (1977), Lizska (1996), Parker (1998), Houser (2010); on the classes and their compositions, Weiss and Burks (1945), Lieb (1977), Sanders (1970), Müller (1993); on the theoretical aspects involved on this issue, Savan (1977b), Short (2007); on its genealogy, Freadman (2004, 2001); on its structural organization, Jappy (1989), Serson (1997), Farias and Queiroz (2000, 2003, 2004), Hoffman (2001); on the description of proposition, Hilpinen (1992), Houser (1992), Stjernfelt (2011); on the modeling of biosemiotic phenomena, Queiroz (2012a, b).

	1st Trichotomy	2nd Trichotomy	3rd Trichotomy
Monadic relation	**QUALISIGN** in itself, the sign is of the nature of an appearance.	**ICON** a sign which refers to the object merely by virtue of characters of its own (CP 2.247).	**RHEME** a sign which, for its Interpretant, is a Sign of possibility.
Dyadic relation	**SINSIGN** in itself, the sign is of the nature of an individual object or fact.	**INDEX** a sign which refers to the object by virtue of some existential relation.	**DICENT** a sign which, for its Interpretant, is a Sign of actual existence.
Triadic relation	**LEGISIGN** in itself, the sign is of the nature of a general type (CP 8.334).	**SYMBOL** a sign which refers to the object by virtue of some kind of convention.	**ARGUMENT** a sign which, for its Interpretant, is a Sign of law (CP 2.252).

**Table 1** Three trichotomies and three kinds of relation. (see CP 2.243)

is described as a qualisign, which notation is designated by the integer 1—it "is any quality in so far as it is a sign" (CP 2.254). If the answer is a dyadic relation, it is a sinsign, which "is an actual existent thing or event which is a sign" (CP 2.245); if it is triadic, it is a legisign, which is "a law that is a Sign" (CP 2.246). The second and the third trichotomies are described, respectively by: icon (1), index (2) and symbol (3); rheme (1), dicent (2) and argument (3). A rheme is "a Sign which, for its Interpretant, is a Sign of qualitative Possibility, that is, is understood as representing such and such a kind of possible Object" (CP 2.250); a "Dicent Sign is a Sign, which, for its Interpretant, is a Sign of actual existence" (CP 2.251); and "An Argument is a Sign which, for its Interpretant, is a Sign of law (CP 2.252).

The results of the trichotomic questions (Table 1) may be combined, in a certain way, by building up a system of cross-relations (see Freadman 2001, 2004; Fig. 1). The kind of relation that answers the first question qualifies (cf. Savan 1977, p. 14) the second, which qualifies the third. A class of sign can be described as a *complex* of relations based on the notion of *logical constraints* (cf. *praecisio*) operating between the categories (monadic, dyadic, triadic relations).

The cross-relations that satisfy the *constraints* are:

(I) 111: a Qualisign is a quality "in so far as it is a sign"; its object is interpreted as being of the same nature—"a feeling of red" (CP 2.254); (II) 211: an Iconic Sinsign is a sign-event interpreted as possibly (rheme) standing for its object (icon)—"an individual diagram" (CP 2.255); (III) 221: a Rhematic Indexical Sinsign is a sign-event interpreted as possibly standing for another event (index)—"a spontaneous cry" (CP 2.256); (IV) 222: a Dicent Sinsign is an sign-event interpreted as

Fig. 1 The 10 classes of signs as a system of cross-relational classes. The paths correspond to the possible compounds of relations. (Figure based on 'Table 1', Merrell 1996, p. 8)
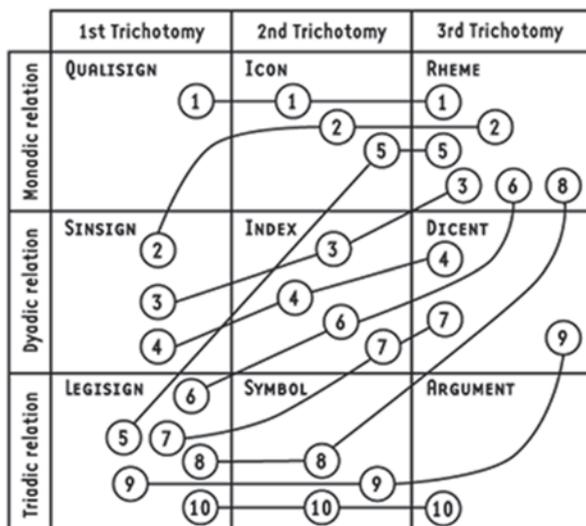
spatio-temporally standing for another event (index)—"a weathercock" (CP 2.257); (V) 311: an Iconic Legisign is a *type*, or a law, a "regularity of the indefinite future" (CP 2.293), interpreted as possibly standing for its object (icon)—"a diagram, apart from its factual individuality" (CP 2.258); (VI) 321: a Rhematic Indexical Legisign is a *type* interpreted as possibly standing for its object (another event)—"a demonstrative pronoun" (CP 2.259); (VII) 322: a Dicent Indexical Legisign is a *type* interpreted as spatio-temporally reacting with its object (another event)—"a street cry" (CP 2.260); (VIII) 331: a Rhematic Symbol is a *type* interpreted as possibly standing for its object (law)—"a common noun" (CP 2.261); (IX) 332: a Dicent Symbol is a *type* interpreted as physically standing for its object (law)—an "ordinary Proposition" (CP 2.262); (X) 333: an Argument is a *type* interpreted as semiotically standing for its object (law) (CP 2.263).

Our interest here is the sub-division of the symbols. According to this typology, there are three classes of symbols, called rhematic, dicent and arguments. A symbol is a general *type* (1st trichotomy) and its object can only be a general (2nd trichotomy). But symbols can also be interpreted as "qualities" or "events" (3rd trichotomy). In other words, a symbol, which is a general, and represents its object as a category of objects, can be interpreted as a possibility (e.g., rheme, hypothesis), as an existing fact (e.g. dicent, proposition) and as a law (e.g. argument, declarative rule). There are many examples of rhematic symbols. Unsaturated mathematical entities, general diagrams, and predicates are usually described as structures of this type. In natural languages, the onomatopoeic words are good examples of symbolic analogical signs. They are dependent on the properties (e.g. phonetic, prosodic) interpreted as shared by signs and objects. For Peirce, "Many words, though strictly symbols, are so far iconic that they are apt to determine iconic interpretants, or as we say, call up lively images" (NEM 4: 243).

Other symbols are interpreted as "existents", or dicent signs, for instance, demonstrative pronouns, nouns, quantifiers, as they appear in logical propositions (CP 2.262)—"A Dicent Sign is a sign, which, for its Interpretant, is a Sign of actual existence" (EP 2:292). The indexes and their fundamental properties are well-known (see Atkin 2005). Thermometers, for instance, represent the "temperature" due the covariation between the height of the mercury column (sign) and the energy of the represented system (object). Importantly, this covariation is not mediated by the action of the interpretant. Of course, it cannot work as a sign without the existence of such an interpreter. But the process is primarily dependent on the fact that two existent events have their natures (topology, shape, dynamics) connected. The example of the thermometer is interesting because there are several rules involved in the interpretation of the device. But it works semiotically mainly because a variation on the dynamics of its object physically *corresponds* to the variations in sign form and structure. This is an indexical legisign. A dicent symbol is a sign interpreted as connected with its object, but its relation with its object depends on a law, rule or acquired habit. Dicent signs in general are able to take truth values—thus conveying information about states-of-affairs (Stjernfelt 2011).

Field research about the vervet monkey alarm-call system revealed that infantile and young adult vervets do not have the competence of either interpreting or emitting these calls efficiently (Cheney and Seyfarth 1990). Learning is involved in vocal production, in using the calls for specific events and responding to the calls. Infant vervets already babble alarms for broad and mutually exclusive categories like "flying birds", but they are unable to recognize whether the birds are predators of their group or not (Seyfarth and Cheney 1986). Although vervet monkeys appear to have an innate predisposition to vocalize calls which are similar to alarm calls for predator-like objects, they have to learn to recognize and respond to those calls. Moreover, the assumption that the mapping between calls and predators can be learned is supported by the observation that cross-fostered macaques, although unable to modify their call production, "did learn to recognize and respond to their adoptive mothers' calls, and vice versa (Cheney and Seyfarth 1998).". In our approach, we assumed that an associative learning competence is used for the acquisition and response to all alarm calls (Ribeiro et al. 2007; Queiroz and Ribeiro 2002). As we have pointed, alarm calls vocalized by vervet monkeys are signs of classes of objects that exist in the real world. These signs are symbols interpreted as indices of the presence of the predator. In Peirce's mature semiotic terminology, alarm-calls are dicent symbols, for the object of a dicent symbol is a general interpreted as an existent. It is exactly this class of processes that some authors have identified as proto-propositional (see Hurford 2007). The importance of this class has been strongly emphasized, since it seems to work between two semiotic classes (index—symbol).

If symbols can be analyzed in three subclasses, only one, namely, argument, possesses metasemiotic properties. Arguments are genuine symbols, types interpreted as generals—"An Argument is a Sign which, for its Interpretant, is a sign of law. Or we may say […] that an Argument is a Sign which is understood to represent its Object in its character as Sign" (EP 2:292). Several anthroposemiotic

phenomena are examples of arguments. Complex chains of reasoning are based on metasemiotic properties, as metalinguistic activities and description of codes and messages. Intersemiotic translations from a semiotic system to another one (e.g., speech > writing; writing > formal languages) only appeared once the material was interpreted as semiotically manipulable, based on laws, or rules. It is to this aspect that what Tomasello et al. (2005) called the "ratchet effect" must be attributed, since it permits accumulation and explosive growth of information. The emergence of symbolic artifacts (semiotic structures physically and culturally available in the environment) produces a very distinct type of cognitive niche (see Clark 2006). They make complex semiotic processes available to attention, perception, etc., opening up a new range of semiotic operations, allowing self-inspection of semiotic complex processes. They make it possible for semiotic systems to think about their own dynamics. What was unexpected to us when performing a semiotic analysis of firefly communication was to find that arguments were also relevant to models of this phenomenon.

Firefly Propositions: An Unexpected Finding

When we try to interpret the firefly flashes involved in courtship or predation based on the basic categories above, we find that three fundamental classes are not sufficient to account for those signs. They seem to combine different aspects of the basic categories. Consider, for instance, that, on the one hand, the flashes point to the presence and location of the emitting firefly, just like the pointing paw of the English pointer indicates the presence and location of a bird. In these terms, the firefly flashes, with their acute figure/ground distinction, can be said to be indexical in nature. However, their pattern also refers to a particular species and gender of firefly, and, for this reason, can be said to be iconic signs, referring to certain qualities of the emitter. It is true that the flashes only refer to a very specific and small part of the iconic qualities of the emitter, but (in the dark) they are very significant, pregnant signs. This is precisely what facilitates their being copied by other species, as it indeed happened in the case of *Photuris* femme fatale fireflies, which signal courtship signs for males of other fireflies, such as *Photinus* males, and when they come to reach what was supposed to be a female of its species, what they find is a voracious predator (Lloyd 1965, 1975, 1986). Indeed, an arms race seem to be taking place between *Photinus* and *Photuris* fireflies, with more complex signalling being selected for in the former, while correspondingly more complex (aggressive) mimicry being selected in the later. This 'arms race' between *Photuris* females and their prey, say, *Photinus* males, was made possible by the fact that the firefly flashes became so conventionalized, in their iconic aspect, that they became stable symbols of the species in question, which are also readable by members of other species.

In order to account for the sign-mediated processes involved in firefly deception, we need to go beyond the basic classification of signs as icons, indices, and symbols.

We should take into account that icons, indices, and symbols are just sign aspects, not mutually exclusive classes of empirical, observable signs. To use a familiar example, photographs are both icons (resembling their objects to different degrees) and indices (being physically connected to their object by the photographic process). The possession of one aspect—e.g. iconicity—does not preclude, thus, the same sign from being also indexical or symbolic.

But notice that, in the case of the fireflies, the sign—the species-specific flash—is referring to its object—the very firefly—in two different senses, combining information about its presence and location, and about its species and gender. These flashes are more complex than simple signs; they are composite signs. We come, thus, to a finding which was unexpected to ourselves: according to Peirce's theory of signs, fireflies are producing propositions!

The situation is more general, however. It may be that, in all cases of deception, we need to turn to Peirce's account of propositions, since propositions are the (composite) signs which may be true or false, and deception is obviously a case of a false proposition.

Robert Mitchell formalizes the concept of deception as follows:

(i) An organism R registers (or believes) something Y from some organism E, where E can be described as benefiting when (or desiring that)
(iia) R acts appropriately toward Y, because
(iib) Y means X; and
(iii) it is untrue that X is the case.

In order to be explicit about the role of signs in the mediation of deception, El-Hani et al. (2010) propose the following modified version of Mitchell's definition:

(i) An organism R registers a sign Y emitted by organism E, and E can be described as benefiting when
(iia) R behaves toward Y, as if
(iib) Y means that X is the case; but
(iii) it is untrue that X is the case.

It is clear, then, that deception demands a situation in which a sign emitted by a given organism and registered by another organism conveys a false information. Only (proto-)propositions can be true or false, and this is one of the reasons why we argue that we should say that the composite signs used by fireflies in deception should be treated as a proposition. Is this too far-fetched?

To answer this worry, let us examine what is a proposition in terms of Peirce's theory. Usually, a proposition is taken to mean linguistically represented signs claiming something about an object (e.g., "S is P"). But, for our arguments to be properly understood, it is important to take into account that Peirce generalized the notion of proposition in his theory of dicisigns (i.e., signs-which-say-something; propositions) to encompass also non-linguistic cases. The proposition forms part of the concept triad rheme-proposition-argument, as discussed above. The rheme is the skeleton of a proposition—but with one or more of its subject slots left blank. Thus "_is blue" is a rheme just like "_ gives _ to _". When one

or more slots in a rheme are filled in by an index (a pointing finger, a demonstrative pronoun, a proper name, etc.), it becomes a proposition. When a proposition is inferred from one or more other propositions in a process of inference, it is an argument.

The crucial structure uniting all propositions, linguistic or not, is that they refer twice to the same object, by means of indices and icons, respectively. In the proposition, the object dealt with must be indicated by means of an index (in the linguistic case: a proper name, a class name, a pronoun, etc.), thus constituting the subject of the proposition, while the predicate of the proposition is presented by means of an icon (in the linguistic case: an adjective, a class name, or verb describing aspects of the object indicated by the index). Thus, a proposition forms a special type of syntactic combination between icon and index, claiming that the two refer to one and the same object.

In order to appreciate how the proposition does not need to be linguistically represented, consider the case of a caricature accompanied by a pointing gesture towards a person. This is a non-linguistic proposition: the pointing functions as the index indicating the subject; the caricature drawing as the icon predicate part. This double reference of the proposition is the reason why it may claim something (iconic) about something (indexical)—and this is why a proposition may be true or false, depending on whether the iconic quality claimed actually exists in the object referred to or not. And this is why deceptive signs must necessarily be propositions. Notice, further, that it is not the indexical part of these signs that lies: in our firefly example, the signs correctly indicate the firefly femme fatale at a specified point in space and time. It is the symbolic-iconic code indicating the character of the animal emitting the sign that does the lying.

From the several complex features of fireflies' communication-mediated interactions, Lloyd (1986) concludes that deception can act as a triggering factor in the evolution of communication complexity. We agree with him. Lies are only possible at the level of—ever so primitive—propositions, claiming that something is the case when it is not. Simple propositions can lie and, by lying, they can trigger increasingly more complex sign processes. This complexity scale should not be mapped, however, onto the distinction icon-index-symbol. It should be rather conceived by other means, e.g., the number of nested levels of communication, the complexity of the sign vehicles, the degree of explicit articulation of the different semiotic functions involved, the complexity of the perceptive and cognitive processes necessary to interpret these signs, etc. (Stjernfelt 2012).

The evolution of communication complexity in fireflies occurs at a very slow pace, since the evolution of the next level of complexity is likely to take an immense amount of generations. While the single game is constantly acted out between particular insects out there, the 'intelligent' step taking us to the next level of deception in this fly-over-fly game is performed by the whole firefly population subjected to natural selection.

We consider these findings, although initially unexpected, to be a crucial part of a proper semiotic modelling of deception in animal communication. It is worth summarizing the basic ideas, thus, in the end of this paper:

1. Our semiotic analysis of firefly communication—in particular, deception—
   shows the necessity of considering even simple sign uses in deceptive strategies
   in biology as dicisigns, proto-propositions, displaying the duplicity of referring
   indexically and signifying iconically. These signs can only be used to deceive
   because they propositionally claim that something is the case, when it is untrue
   that it is indeed the case.
2. This analysis casts doubt upon the widespread assumption that the distinction
   between icons, indices, and symbols can be mapped directly onto biological evo-
   lution so as to form three distinct, consecutive phases. Rather, all three aspects
   of object reference are present in different combinations already in relatively
   simple biological sign uses. Firefly signal patterns are a case in point, hinting at
   a continuous scale between simple icons at one end and symbolical stylizations
   of icons at the other end.

If we consider the following continuum—the flash pattern as an icon of a firefly,
the stripe pattern as an icon of a zebra, two half circles of the breasts as an icon of a
woman, the outline of the body shape as an icon of a man—, we can see that, in all
these cases, the patterns mentioned have iconic qualities allowing conspecifics to
recognize each other. But they do not display the same amount of stylization nor the
same degree of arbitrariness in relation to other aspects of the animals' appearance.

The flash pattern is evidently the most symbolic of these cases, because it is ex-
tremely stylized, can be repeated identically with a stable meaning, is used only for
signifying mating behavior and only at a specific time (night), and could, in theory,
be substituted by another pattern. Moreover, it is the only sign facilitating the meet-
ing between the firefly males and females in the dark. By contrast, each of the
other three signs mentioned above are only one among many other possible iconic
signs among conspecifics (smell, sound, other visual icons, etc.). It is the specific
signification of the firefly flashes that make it possible that they are used in such
a manner that fireflies are deceived by apt mimics of the species-specific flashes.
They are deceived by different manners of using these proto-propositions that both
refer indexically and signify iconically.

3. Our analysis also shows the need of considering two timescales to understand
   the evolution of deception (in the case of fireflies, and, certainly, in the case
   of many other deceptive mimicry phenomena): one of individual, highly rou-
   tinized sign exchanges involving particular firefly specimens with relatively
   small interpretation plasticity, and one of the arms race between species lead-
   ing to the evolution of nested deception strategies. Such deceptive strategies
   in general—between predator and prey, between species competing for related
   ecological niches, between individuals or groups within the same species—
   may constitute a major motor in the semiotic evolution of complex signs, to
   some extent analogous to the code maker-code breaker arms race in human
   military intelligence.

In summary, the study of firefly signal patterns seems very promising for further
investigation, both empirical and theoretical, of the role of biological deception in
the evolution of animal communication.

Discussion

The vast morphological variety of empirically observed semiotic processes is usually reduced to three (non-exclusive and hierarchically organized) classes of signs based on the sign-object relation (icon, index, symbol). But there are a number of semiotic phenomena which correspond to "intermediate" classes of symbols such as linguistic deictic, proper names, logical quantifiers, which are cases of "indexical symbols", or musical onomatopoeia, which are "iconic symbols". In order to more accurately describe these classes, Peirce developed several classifications. According to the ten-fold classification, a sign is grounded in some property, event, or regular pattern, by virtue of which it stands for some quality, occurrence, or law to a third element, an interpretation of possibility, physical connection or rule-based tendency. Through such classification, it becomes possible to represent more accurately several morphological variations that we can empirically find.

In the symbolic sign process described above, what is communicated from the object to the interpretant through the sign is a lawful relationship between a given type of alarm and a given type of predator. Generally speaking, a symbolic sign communicates a habit embodied in an object to the interpretant as a result of regularity in the relationship between sign and object (see Queiroz and El-Hani 2006). If iconic signs inform a certain quality shared by signs and objects and indexical signs inform a direct physical connection between signs and objects, then symbolic signs inform a habit embodied in the object to the interpretant as a result of a law-like regularity in the relationship between sign and object. Constraints imposed by spatio-temporal presence of an existent object are not functional in symbolic processes.

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