

Conceptual analysis of social signals: the importance of clarifying terminology

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Abstract As a burgeoning field, Social Signal Processing (SSP) needs a solid grounding in the disciplines that have developed important concepts in the study of communication. However, the number and diversity of terms developed in linguistics, psychology, and the behavioural sciences may seem confusing for scholars who are not versed in the subtleties of conceptual analysis and theoretical developments. Indeed, different disciplines sometimes use the same term to mean different things or, conversely, use different terms to mean the same thing. The goals of this article are to present an overview of the different concepts developed in the various disciplines that studied animal and human communication, and to understand the differences and commonalities between concepts emerging from these disciplines. We conclude that such an understanding will greatly improve the efficiency of pluridisciplinary research projects, for the advancement of SSP requires that we look at the complexity of communication from different angles.

Keywords Communication · Social signal processing · Non-verbal behaviour · Social signals · Social cues · Meaning

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Although it is commonly used to characterize the treatment of socio-communicative behaviour by organisms [80, 100] or by computer algorithms [74], the use of the term “Social Signal Processing” (SSP) as a label for an academic field originates in a paper by Vinciarelli, Pantic, & Bourlard [97]. This paper described the importance of looking at social interactions in a holistic way, considering not only the verbal exchanges between individuals but also the nonverbal aspects of face-to-face communication. The aim of that foundation paper was to stimulate research towards automatic analysis of human communicative behaviour with the ultimate goal of building socially intelligent machines [97]. Clearly, Vinciarelli et al. [97] was a call to unite the branch of computer science interested in the automatic analysis of human social behaviour with researchers in the “human sciences” investigating face-to-face communication. Early writings in SSP, however, were not quite explicit as to what exactly was meant by social signals, sometimes importing concepts from evolutionary biology (e.g. see [75, p. 2]), social psychology [4, 22], and psycholinguistics [57]; while placing a strong emphasis on nonverbal behaviour. Viewed from the outside of computer science, early writings in SSP could give the feeling that anything deemed to be important in a social interaction should be considered a social signal. This is, of course, not the case.

In order to anchor their discipline in the rich conceptual background developed in linguistics and behavioural sciences, SSP researchers are faced with the difficult task of defining a theoretical framework that describes the phenomena they are eager to automatically detect, interpret, and synthesize. The reliance on theories developed in the behavioural sciences and linguistics is therefore crucial if the output of SSP is to be considered credible within a wider scientific community. Collaboration between psychologists, behavioural scientists, linguists and computer scientists is

therefore an essential step in the progress that SSP will make towards a respected discipline.

The commitment of SSP to pluridisciplinarity does not come without problems. The adoption of a theoretical framework for SSP faces a major issue: the great diversity of conceptual ideas about social signals and communicative behaviour stemming from the many approaches that study human interaction. Psychology, linguistics, and ethology have developed a myriad of ideas, definitions, and methods for the study of communication. In itself, this may be seen as a strength more than a weakness because having multiple approaches increases the potential for a good understanding of the complexities of human behaviour. This diversity only becomes an issue when people of different traditions come to work together in pluridisciplinary projects in which they have to cooperate to make a substantial move towards scientific breakthrough. The increasing specialization that characterizes most scientific disciplines can be a barrier to pluridisciplinarity, for it can hinder communication between scholars who understand and define concepts in different ways.

In fact, for communication to be successful, one has to use terms that will be understood by all members of a network in an agreed upon way. In an attempt to overcome this difficulty, we decided to describe the different approaches and concepts adopted by the human sciences studying human interaction as represented in Social Signal Processing research. This paper presents a non-exhaustive glossary of terms generated by different fields (ethology, social psychology, cognitive psychology, linguistics, semiotics, and mathematics) to study communication (Table 1). While discussing the definitions of key concepts that revolve around social signalling, we will present commonalities and differences between a variety of approaches, so that scholars who are not familiar with the different disciplines can have a clearer idea of what the different positions are.

Our goal is not to create a common definition for the concept of social signal because it would deny the specificities of each field and would constitute, for some, a loss of conceptual clarity. In addition, creating a summary-like definition would be counter-productive for SSP because it would close the door to scholars who may feel that their work is only partially recognized by the field. As a pluridisciplinary venture, our aim is to avoid the creation of a monolithic view that is unlikely to be adopted by the scientific community at large, or that may block the development of new ideas or research projects. Instead, our goal is to expose our diversity in a way that respects everyone's research agenda and that encourages adhesion of new members to the SSP community. For the reasons that it is virtually impossible to create definitions that include everyone's opinion (some of the reasons will be discussed in a later section), and that everyone's opinion should be respected, the present glossary

of concepts is an expandable collection of the different approaches used to study social signals and human communication. This paper presents some concepts used by the major actors in communication research and briefly discusses the differences and commonalities between approaches.

1 Information and meaning

One of the most influential models of communication derives from efforts aimed at improving the efficiency of message transmission over long distances [90]. This laid the foundation of the Sender-Message-Channel-Receiver model of communication [12], a model that massively influenced modern research in linguistics, psychology, and ethology. Cognitive psychology further developed theoretical models that show how different levels of intentionality [2, 39], or goals (internal or external, conscious, unconscious and tacit [20, 76, 78]) may contribute to the differentiation of signals. In addition psychology of communication developed “dialogical” [37] and discursive approaches [43] that consider not only the sender's perspective but also the addressee's, seen as a contribution to the sender's message. In this perspective, linguistic communication is considered as a shared [3] and dynamic process of construction/reconstruction of meanings [24, 60, 98], where the “constructed” meaning is the result of inputs from both sender and addressee.

Meaning is considered a major aspect of communication and this concept occupies a central role in the field of linguistics and philosophy (in particular the philosophy of language). The notion of *meaning* is complex and tricky and we will point out some issues here. According to Saussure [83], meaning is the conceptual side—the signified—of a sign. The form of a sign, he called the “signifier”. A sign is thus a pairing of a signifier and a signified. The meaning (an internal abstract representation that can be attached to some signal, for example a word) should be distinguished from the referent (the concrete or abstract object a signal refers to). Frege [36] made an important distinction between “Sinn” and “Bedeutung”, commonly translated as “sense” and “reference”. The classical example to illustrate this distinction is the meaning of the expressions “Morning Star” and “Evening Star”. As they refer to the same object, they have the same referent but their sense is different.

In the Sender-Message-Channel-Receiver model of communication, the Sender encodes meaning in some particular form which is sent to the Receiver who decodes it. For communication to work in this model, it is important that Sender and Receiver share the code. Typically, in language, the code is based on conventions that speakers need to learn. But the way in which the meaning and the form are related can differ.

Table 1 Definitions of important concepts for social signal processing

Ethology	
Signal (information)	Animal signals are acts or structures that alter the behaviour of other organisms, which evolved because of that effect, and which are effective because the receiver's response has also evolved [56]. Signals must carry information—about the state or future actions of the signaller, or about the external world—that is of interest to the receiver. A signal is the vehicle for the provision of information from a sender to a receiver [14].
Signal (influence)	Animal signals are specialized, species-typical morphologies or behaviours that influence the current or future behaviour of another individual [67].
Cue	A feature of the world, animate or inanimate, which can be used by individuals as a guide to future action [44].
Display	Behaviour pattern that has been modified in the course of evolution to convey information [11]. Displays are usually constituted of several components, like cues and signals.
Handicap	A signal whose reliability is ensured because its cost is greater than those required to efficiently convey the information [103]. The signal may be costly to produce, or have costly consequences [96].
Index	A signal whose intensity is causally related with the information that is being signalled and that cannot be faked [55]. Indices are equivalent to performance-based signals [35].
Minimal-cost signal	A signal whose reliability does not depend on its cost (different from a handicap) and which can be made by most members of a population (different from an index) [56].
Conventional signal	A signal that has no physical or physiological reason to be correlated with underlying quality [54]. A signal which design is more or less arbitrarily related to a message. Since many of these signals can carry the same message there is a need for consensus among perceivers [41].
Psychology	
Cue	A stimulus that serves as a sign or signal of something else, the connection having previously been learned [101].
Distal cues	Externalization of stable traits or transient states, can be motor expression or physical appearance [15, 85].
Proximal percept	Mental representation resulting from the perceptual process of distal cues [15, 85].
Social signal	Human social signals are acts or structures that influence the behaviour or internal state of other individuals, that evolve because of that effect, and that are effective because the perceiver's response has also evolved; signals may or may not convey conceptual information or meaning [58].
Social signal	Communicative or informative signal that, either directly or indirectly, conveys information about social actions, social interactions, social emotions, social attitudes and social relationships [77].
Sign	Refers to an act that is informative but that was not necessarily produced to communicate information [33].
Emblem	Nonverbal act which has a direct verbal translation that is known by all members of a group, class, or culture [30, 34]. Emblems are not necessarily arbitrary with regards to their meaning and can be iconic (i.e. their form resembles their meaning).
Illustrator	Movement directly tied to speech that illustrates what is said verbally [30, 34].
Regulator	Act that maintains and regulates the conversation between two or more individuals [34].
Manipulator	Act that represents adaptive efforts to satisfy bodily needs, actions, to manage emotions, to develop interpersonal contacts, or to learn instrumental activities (see also <i>adaptor</i> in [34]).
Emotional expression	Observable act that is specific to a particular emotion [32, 95], or to an underlying emotional dimension [86].
Linguistics and semiotics	
Sign	A two-sided psychological entity encompassing a physical side (signifier) and a conceptual side (signified, the meaning), where the signifier “stands for” the signified, and is associated with it [83]. Different types of signs (e.g. icon, index, symbol) are distinguished for the different ways in which the meaning is associated with the signifier [71].
Index	A sign pointing to the meaning by means of a causal relation to it. For example, tracks and symptoms indicate their cause: smoke indicates fire, footprint indicates animal.
Icon	A sign that physically resembles what it stands for. For example, onomatopoeic words.
Symbol	A sign with an arbitrary connection between signifier and signified. For example, words in a language.
Signal	The word “signal” is not typically used in linguistics. Allwood [1] uses the term as follows: A manipulatory action that is intended to make a receiver apprehend a certain object. Clark [23] uses the term to refer to “the acts by which one person means something for another” (these are not necessarily linguistic acts).
Speech act	An act performed through language [7, 88]. Every sentence is a speech act, and has a locutionary aspect (it is an action performed by uttering words), an illocutionary aspect (in uttering a sentence one performs an act towards someone else) and a perlocutionary aspect (through language people can produce effects on other people, like being alerted, scared, persuaded. . .). A speech act includes a performative (the Speaker's communicative intention, of informing, asking, warning, apologizing. . .) and a propositional content.

Table 1 (Continued)

Indirect speech act	A speech act which real meaning is different from the apparent one. For example, a request in form of a question (“Can you pass the salt?”) [88].
Communicative act	An act performed by any productive modality, gaze, gesture, facial expression, aimed at conveying to an Addressee some meaning that includes a performative and a content [76].
Act of display	A manipulatory action that is intended to make a receiver at least apprehend or attend to a certain object, through some manner of apprehension like direct observation or influence [1].
Turn-taking	The fact that participants in a conversation speak one after the other, which is governed by specific rules. The fulfillment or violation of turn-taking rules in a conversation provides cues about its cooperative or competitive structure [28, 82].
Backchannel	Feedback and comments provided by listeners during face-to-face conversation, through non-intrusive short verbalisations and nonverbal signals [99].
Processes and concepts associated with the production and perception of social signals	
Communication	Process in which meaningful information is made available through the use of signals produced by a sender and processed by a receiver. An alternative view considers communication as a reciprocal process in which signallers attempt to manage the behaviour of perceivers, who in turn must assess the implications of signals with regards to their own interests in a given context [65].
Sender/Signaller	The producer of a given signal.
Receiver/Perceiver	The perceiver of a given signal or cue. The perceiver need not always be in the vicinity of the signaller to perceive the signal (e.g. in assisted communication).
Information (mathematics)	Any physical property of the world that reduces uncertainty in the individual that perceives it [90].
Code	Principle of correspondence between the act and its meaning [34]. The code can be intrinsic, extrinsic, and iconic.
Encoding	The process, taking place in the signaller, of relating the distal cue and its meaning. Transfer of information in one domain (e.g. thought, stance, attitude, emotion) to another domain (muscular contraction, blood concentration, chemical, etc.).
Decoding	The process of relating the proximal percept to a semantic category or some other form of representation, using the same code that served to elaborate the signal.
Modality	The body organs or sensory system involved in the production and the perception of signals. Humans communicate in various modalities: auditory, visual, olfactory, and tactile.
Channel	The different systems that compose each modality. For example, in humans the auditory modality includes language and nonverbal vocalizations; the visual modality includes facial expression, gestures, postures, etc.
Multimodality	The principle through which signals involve more than one modality of production and perception, for example laughter uses the auditory and visual modality.
Context	All the cues present in the physical and social environment of a perceiver as well as perceiver’s characteristics that surrounds the signal.
Object	In Peirce’s theory, an object (or semiotic object) is a subject of matter of a sign and an interpretant. It can take various forms, e.g. a thought, an event, a material thing, an argument, or can even be fictional. Objects can be immediate (the object as it is represented in the sign) or dynamic (the object as it really is).
Interpretant	In Peirce’s theory, an interpretant is the sign’s meaning or ramification, it is the representation of the difference that signs (undeceptive signs) would make for perceivers. The dynamic interpretant is the effect that the sign actually has on a perceiver, whereas the final interpretant is the effect that the sign would have on the perceiver given optimal circumstances, or the sign’s purpose.
Referent	An idea, event, or material object that designates what a sign “stands for” [21]. The object which the signal mentions or to which it refers [36, 64].
Meaning	The conceptual or sensori-motor information that can be drawn from some perceptual stimulus. The meaning is the conceptual side—the signified—of a sign [83] and it is distinct from the referent. There are variants of the concepts of meaning.
Natural meaning	Natural meaning makes reference to the stable relation that exists between cause and effect. Grice [38] speaks of <i>natural sense</i> for verbal expressions that represent such relationship.
Meaning non-natural	Non-natural meaning (meaning _{NN}) makes reference to the intention a speaker has when communicating something to an audience [38]. This definition implies that someone means (meaning _{NN}) something by some utterance if and only if it is uttered with the intention that the addressee recognizes the intention underlying the utterance produced.
Appeal	In Bühler’s [16] Organon Model, appeal refers to the way a sign affects the perceiver, independently of the content of the sign [46].
Inference	New information drawn from previous information through a process of reasoning.
Ground truth	A term, with origins in cartography and aerial imaging, used to describe data that can be taken as definitive, and against which systems can be measured.



Fig. 1 A mixture of iconic and symbolic

Peirce made a distinction between three types of signs: *icons*, *indices*, and *symbols*. Icons, resemble the objects they represent perceptually. Pictures and diagrams are typical icons. Indices bear a spatial or causal connection between the form and what they represent. Classical examples to illustrate indices are the weathercock or the spots that indicate measles. For symbols, the relation between form and meaning is by rule, typically by convention. Words and phrases are prototypical symbols in this sense.

A sign does not necessarily belong exclusively to one class. Consider, for instance the traffic sign of Fig. 1. By convention, the sign tells drivers that a traffic light is approaching. The meaning of this sign is laid down in the traffic code and therefore we can say that this is a symbol. In particular the use of the red triangle pointing upwards is a convention to mean: “watch out, you are approaching something”. The picture of the traffic light is making it clear what it is that one should be watching out for. This element of the meaning of the traffic sign is thus presented iconically.

In Grice [38]—one of the central papers on meaning—a distinction is made between the concept $\text{meaning}_{\text{NN}}$ (where NN stands for non-natural) and “natural meaning”. Indices are typical instances where natural meaning is involved. The central concept in Grice’s notion of $\text{meaning}_{\text{NN}}$ is *intention*: someone means something by some utterance if and only if it is uttered with the intention that the addressee recognizes the intention underlying the utterance produced. For Grice “what words mean is a matter of what people mean by them” [40, p. 340]. To illustrate the concepts a bit further, consider Grice’s account of frowning.

If I frown spontaneously, in the ordinary course of events, someone looking at me may well treat the frown as a natural sign of displeasure. But if I frown deliberately (to convey my displeasure), an onlooker may be expected, provided he recognizes my intention *still* to conclude that I am displeased. [38, p. 383]

This shows that communication can work in various ways. In the case of the deliberate frown, the onlooker may rec-

ognize the fact that the frown is deliberate or the onlooker might miss the deliberative aspect.

The relation to meaning and the intention of the signaller are major defining criteria in the linguistic approach to social signals. The concepts of sign and referent are also central to the linguistic approach, which, because of its early focus on human language and symbolic communication, has mostly developed around the idea of information transfer. When people communicate using natural language, they utter words and phrases not just to convey the meaning that is conventionally attached to the expressions. The pragmatic level considers that a particular combination of words—a sentence—also constitutes a social action performed towards others [7]. Searle [88] called these social actions speech acts. They include the Speaker’s performative (the communicative intention of informing, asking, warning, apologizing. . .) and propositional contents. This can take interesting forms. Consider for example, the case where somebody replies to the question “Shall we go out for a walk?” with the utterance “It’s raining.” Besides being an utterance that can be truthful or not (the propositional content in semantic terms), it could also “mean”, on the level of pragmatics: ‘No, I don’t want to go out’ or ‘We should take an umbrella with us’. These implied meanings are the essence of social interaction. They form a huge challenge for Social Signal Processing.

If, linguistically, signals are generally understood as having stable connections to corresponding meanings; the advent of nonverbal communication research (e.g. [5, 42, 59]) did not come with a massive change of paradigm, as the transmissive model of communication (as pointed out by [21]) remained the foundation to understand the role of nonverbal cues in social interaction. Mainstream research in animal and human communication indeed considers that social signals convey information and meaning to receivers. In this view, a signal constitutes material that is coded by a sender, that is transmitted through dedicated channels (e.g. face, voice, body) and that is decoded by receivers who thereby retrieve information and meaning. Owren & Bachorowski [66] claimed that models based on this approach work on a number of assumptions that may not necessarily apply to nonverbal communication. For example this view assumes that information is encoded into a signal, which then becomes a vehicle for socially relevant messages. The effect of context on the interpretation of social signals is at odds with this view because the meaning of an encoded message should be intrinsic to the signal itself, making its interpretation less subject to influence by contextual information.

An extreme case of nonverbal signal that do not involve intrinsic meaning is the pointing gesture. According to Tomasello [94], communicative gestures such as pointing (or gazing) do not contain encoded information in and of themselves but function to orient perceivers’ attention to

specific contextual information. Rather than being encoded in the signal, the relevant information has to be inferred by perceivers from contextual cues and from shared knowledge about that context (physical and social environment, past experiences, etc.). Consequently, the semantic principles that apply to the study of human language should not generally apply to the study of other social signals like human nonverbal behaviour [66], or animal signals [79]. In other words, the semantic or referential component of human language may not necessarily be shared by other channels of communication.

2 What are social signals?

Different disciplines adopt different ways of defining a social signal. For example, in ethology, animal signals are acts or structures that affect the behaviour of other organisms, which evolved because of that effect, and which is effective because the receiver's response has also evolved [56]. Most ethologists contend that signals are vehicles that materialize the transfer of information from a sender to a receiver [14, 45, 93]. However, the exclusive reliance on information transfer may result more from researcher's tendency to model animal communication on human language than from solid conceptualization of key terms such as information and encoding [79]. In evolutionary terms, the transfer of information is not a requirement for a signal to evolve, provided that the signal provokes a response in perceivers that is adaptive to signallers [51]. A crucial question is whether the perceiver's reactions to signals are mediated by psychological mechanisms of inference that maximize acquisition of information before releasing a response. From an evolutionary point of view, such filtering mechanism is expected because it would optimize perceivers' responses to social contingencies, for example by preventing social exploitation from skilful signallers. However, the existence of perceptual mechanisms that evolved to infer of adaptive social information is not in itself evidence that social signals are vehicles of encoded messages.

Consequently, there is a divide within the field of ethology as to whether information or influence constitutes the most important factor in signalling. Owren, Rendall, & Ryan [67] proposed a definition of animal signalling based on social influence, in their words, "animal signalling is the use of specialized, species-typical morphology of behaviour to influence the current or future behaviour of another individual" (p. 771). This definition is based on the idea that communication is a process through which individuals manage their social environment via influence and assessment of other group members, rather than a process of transferring (reliably or not) pieces of information to others [65]. The

importance of social influence in communication is also underlined in social psychological theories of nonverbal behaviour [29, 68] and constitutes a central aspect of the definition of human social signal proposed by Mehu and Scherer [58], who reformulated the ethological definition of animal signalling to include the specificity of human symbolic communication. The latter authors defined human social signals as acts or structures that influence the behaviour or internal state of other individuals, that evolve because of that effect, and that are effective because the perceiver's response has also evolved; signals may or may not convey conceptual information or meaning [58]. Mehu & Scherer's definition of social signals can be viewed as a way to combine two major aspects of human communication: information transfer through the use of symbols and social influence.

Another view on social signals is provided by Poggi & D'Errico [77], who define a signal as "social" by its content: "social signals" are those signals that provide information about *social facts*, i.e. social actions, social interactions, social emotions, social attitudes, evaluation and stances, social relationships and social identities, where *social action* is defined, for instance, as an action directed to another agent while viewing it as a self-regulated agent, with its own goals [25]. So, for *social interaction*, defined as a sequence of social actions performed by two or more (biological or artificial) agents towards each other, typical social signals are turn-taking and backchannel signals, through which participants in a conversation respectively manage the turn-taking system, or provide feedback about their following and understanding.

Other social signals concern social emotions. In fact, some emotions are "social" because of their argumentative structure: they are two-arguments predicates, in that their logical structure involves not only the person feeling the emotion but also the other "towards whom" the emotion is felt, as in envy, admiration, compassion. Other emotions are social by their function of preserving the social goals of image and self-image (e.g. shame, embarrassment, pride); while guilt and compassion preserve the goals of preventing an agent from doing or accepting harm to others [78].

Empirical findings in nonverbal behaviour research conducted in social psychology have played a major role in the development of SSP (see [4, 22], for the most cited psychology papers in SSP). Even though the term "signal" has been used in social psychology, the latter discipline has not provided a formal definition of the concept. Instead, psychologists seem to endorse a general dictionary definition of signals that, by default, takes the assumptions of information transfer (e.g. [10, 31, 52, 91]). In addition, psychologists tend to use the term indicator, sign, signal, and display interchangeably (e.g. [18, 50]), without nuancing these terms. This is not to say that psychologists did not show interest in classifying human nonverbal behaviour in different

types. For example, Ekman [31, 33] made the distinction between emotional and conversational facial signals. Specific categories of nonverbal acts were proposed by Ekman and Friesen [34], who distinguished five major classes of nonverbal behaviour: emblems, illustrators, adaptors (or manipulators), regulators, and emotional expressions. Although not explicitly defined as social signals, these categories are based on functional aspects of social interactions as well as on the postulated antecedents of behaviour, which are often taken as the encoded meaning of the signal.

The variety in definitions may be partly explained by the use of different methodologies and the different empirical questions that have driven research activities in different fields. For example, ethology has mostly focused on the adaptive significance of behavioural patterns for the organisms displaying them and the selective pressures responsible for the evolution of signals [47]. Social psychology, however, has been mostly interested in the direct causes and mechanisms of social behaviour and has always placed a greater interest in discovering the significance or meaning of a particular behaviour [81, 86]. This tendency was particularly salient in facial expression research, where scholars have argued over the meaning of facial expression, if they convey emotional states, cognitive evaluations, action tendencies, or social motives [87, 102]. Finally, aside from studying the structure of language and its meaning, linguistics—in particular the branch of pragmatics—investigates how utterances are used in social actions [7, 88] but also how language is used in relation to context and other signals (e.g. hand and head gestures) in order to convey meaning [3]. The diversity in research methods and theoretical interests led scholars to use different terms to describe the same thing, or sometimes the same term, e.g. social signals, to describe different ideas. By no means should this signify that one approach has more authority than the other, or that a research question is more relevant than another. The only drawback is that this state of affair may create confusion in scholars who are interested in social signals but are not familiar with the various ways of proceeding in human and behavioural sciences.

The difficulty in making a definition that satisfies everyone may not necessarily come from academic disparities but rather from the importance that is given by different authors to the role of information in communication. As we have seen earlier, there is an on-going debate in ethology as to whether information transfer should be the critical feature of animal communication [65, 67, 79, 89]. This debate has been carried into the field of SSP, as it is believed that some aspects of human communication (mostly the non-symbolic aspects, like nonverbal vocalizations, or a large proportion of facial movements) do not function to convey encoded information from a sender to a receiver but to help individuals manage their social environment through social influence

[58]. The emphasis on social influence in the ethological definition of human social signals implies that all human social signals have the potential to exercise influence on other individuals but only some of them (the symbolic signals) are vehicles of encoded information.

The definition of social signals proposed by Poggi & D’Errico [77] places the emphasis on information transfer as the main defining character of social signals. For the latter authors, it is not sufficient that a behavior or structure influences another individual to be called a social signal, it also has to carry information about social facts, i.e. social actions, social interactions, social attitudes and social relationships. On the other hand, although Mehu & Scherer’s definition acknowledges that social signals may convey information, it is not a requirement for an entity to do so in order to be called a social signal, as the most important aspect for that definition is that the behavior (or morphological structure) functions to induce a response in perceivers that is adaptive to the signaler (whether or not the perceiver benefits from gaining information). In addition, Poggi & D’Errico [77] considers what ethologists call *cues*, i.e. informative but not communicative entities (Table 1), as social signals because social facts can also be inferred from them. Ethological definitions, however, require that a behavior or morphological structure has evolved as a result of their effects on perceivers in order to be called a social signal [56, 58, 67]. In sum, although both approaches recognize that information transfer and influence are important aspects of human communication, these principles are given different weights in the definitions of social signals.

Beside the different uses of the term *social signal*, another example of using the same term to mean different ideas is provided with the use of the term *cue*. Ethology and perception psychology both make use of the term *cue* to describe external stimulations. Although these disciplines use different definitions for the same term (Table 1), the definitions offered are not necessarily opposed. When perception psychologists talked about the term *cue* they did not necessarily have in mind the study of communication and therefore did not need to define the term in relation to signals, to the contrary of ethologists, who have been versed in communication research from the early days of their discipline. The core element of a *cue*, as defined by ethologists and perception psychologists, can therefore be said to be very similar, as it underlines the association made by perceivers between the *cue* and some relevant information. The concept of *cue* is also very similar to the concept of “*sign*” taken in its simplest form, i.e. as meaning something which occurrence indicates the occurrence of something that may not be directly perceivable (for example, the presence of smoke indicates fire or combustion). A *sign* is also distinct from a *signal* because its occurrence is not necessarily linked to communication; but, like any other stimulus, can be interpreted by perceivers to guide adaptive actions.

3 Commonalities between approaches

Although we can see that research domains mostly differ in the detailed elaborations they made with regards to the nature of signals, their function, and their informative values; the different views share a few features and principles that are important for communication research. First, some acts are considered functionally or intentionally communicative (e.g. signals, emblems, communicative signals); whereas others are simply considered as informative (cues, signs, informative signals), suggesting that information can be derived from them although they have not evolved, or are not intended, for communication.¹ The latter aspect most probably reflects people's tendency to search the environment (social or physical) for information they can use to their benefit, independently of communicative demands. Most theories of communication therefore recognize that inference based on proximal percepts is a major feature of communication that can be relatively independent from the function and intention (conscious or unconscious) to send particular signals.

Most theories also recognize the existence of signals which relation to meaning is arbitrary and follows social conventions: symbols in linguistics [71], conventional signals in ethology [41], and emblems in social psychology [30, 34]. In linguistics, symbols are understood as signs that represent their objects independently of any resemblance to them (unlike icons) or independently of any natural connection to them (unlike indices), but “because dispositions or factitious habits of their interpreters insure their being so understood” [72, pp. 460–461]. In ethology, conventional signals are seen as signals which design and form is arbitrarily related to the message conveyed [41]. Since the same information could, in principle, be conveyed by many different conventional signals, perceivers need to agree on the meaning of these signals. Finally, although not all emblems are arbitrarily coded, they are believed to have a much higher proportion of shared than idiosyncratic meaning [34], which would bring them closer to actual symbols.

Most approaches also recognize that social signals are perceivable entities that produce a biological, cognitive or behavioural response in a perceiver. For example a central aspect of the ethological definition of social signals is that signals have an influence on perceivers. In the same way, the concept of appeal—defined by Bühler [16] as the way signs affect perceivers—also considers social influence as an important factor in communication. The concept of interpretant introduced by Peirce [73] also covers the effect the sign has on perceivers. In social psychology, one of the postulated functions of nonverbal behaviour is to exercise social influence [17, 68]. Given the observation that reactions

to social signals can occur below the level of consciousness [27, 61], the question of whether social influence is mediated by mental inferences about meaning is still debatable. Since automatic reactions to social signals most probably rely on structures that are evolutionarily more ancient than the cognitive structures responsible for symbolic communication, it is unclear whether fast reactions to social signals are mediated by the transformation of proximal percepts into amodal, language-like, symbols; or if they result from direct connections between perception and action [26]. Matters are further complicated by the observation that semantic priming can also occur without awareness [62, 92], indicating that symbolic messages can be processed automatically. A major challenge for future research in communication will be to specify the nature of mental representations involved in the processing of social signals, more precisely to determine whether these representations occur in a symbolic format or, as suggested by embodiment theorists, if they are grounded in their physical context and rely on the brain's modality-specific systems [63]. Answering such questions requires that researchers consider alternative views on communication, for solutions may well come from the integration of different approaches.

Another commonality between approaches is the recognition that communication is multimodal, i.e. it involves the interaction between different production and perception modalities [3, 9, 70, 76]. The study of multimodal communication should be the first research topic to benefit from integrating different conceptual approaches. In a recent article, Mehu & Scherer [58] proposed that the various components of human multimodal signals have evolved to implement two evolutionarily important aspects of human communication: information transfer [14] and social influence [67]. Complex communicative units such as multimodal signals could indeed carry components that are designed to increase information transfer [6, 49] and components that increase the likelihood of a response by perceivers [8]. Such interactions between components may be particularly critical in human communication system, as it is rich in symbolic messages and non-symbolic components. Researchers in multimodal communication should take these two aspects into account if they want to enhance the predictive value of their findings.

4 Conclusion

The absence of consensus in definitions most likely comes from natural drifts in the elaboration of concepts by the different disciplines accentuated by the lack of communication between these disciplines. The object of interest—human communication, and the realities associated with it, e.g. social signals, remain the same across disciplines. The different approaches adopted by academic fields are reflected

¹Note that within the field of ethology, some authors consider signals as information carrier (e.g. [14, 103]); while other authors see signals as mostly influential [51, 65, 79].

in differences in terminology, or in differences of meaning for similar terms. Rather than underlying the differences in views, conceptual developments in Social Signal Processing should aim at emphasizing their commonalities and understanding the origin of their differences in order to avoid unnecessary conflicts between researchers. Finally, it is the responsibility of each SSP scholar to get familiar with the different approaches and to choose the concepts that are most appropriate for his/her specific research goals.

Increased communication and exchange between disciplines should also, ultimately, lead to a better integration of the different concepts in a cohesive framework. For example, modern ethological theory of signalling was strongly influenced by game theoretic models proposed to explain the evolution of communication [19, 53, 69]. The consideration of costs and benefits of signalling behaviour has now become paradigmatic in evolutionary approaches to communication and has stimulated new ways of looking at behavioural data in a variety of academic fields like ethology [48], economic psychology [84], or anthropology [13]. The constructive interactions that have developed between the fields of economics and evolutionary biology is a good example of how the integration of concepts and communication among disciplines lead to increased understanding of complex phenomena.

A closer examination of the different concepts elaborated by the different disciplines revealed a number of commonalities and made the apparent differences between fields look less important than they seem at first glance. Such commonalities reflect the similar observations that have been made on human communication and are expected given the common topic of study. Concepts that are common across disciplines are likely to be long lasting, for they appear to be relatively independent from the philosophical and methodological orientations adopted by researchers. Commonalities of this sort make collaborations between disciplines possible and create the bridges necessary for pluridisciplinary projects to run smoothly.

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