Rock art and language (in a nutshell)

James Dodd *

Summary

This contribution addresses particular aspects of the complex debate concerning the contentious link between rock art and language. As current scholarship in the fields of archaeology, linguistics and epigraphy are reconsidering the role and extent of visual communication within prehistoric societies, it is arguable that the abstract definition of language, and the sender: message: receiver (SMR) model of communication associated with it, proposed in 1945 by mathematician, electrical engineer, cryptographer, and founder of the field of information theory, Claude Shannon (1916-2001), provides a useful framework for the scientific study of rock art. Using Shannon's propositions as the basis for a data model, rather than a theoretical one, opens up a range of analytical possibilities, which are not dependant on rock art having functioned as a means of communication in prehistory.

If we are prepared to accept Shannon's definition of language, the SMR model, and consider rock art from an informatic perspective, it is arguable that all the basic properties of a communication system are present. Fundamental to the functioning of such a model are the existence of mappings between the images and some underlying significance, be it trivial or complex. The situation in practice can be understood with reference to ethnography and the recently published typology constructed by Morin, Kelly and Winters (2020), which distinguishes between four types of codes according to their speech-boundedness and information carrying capacity. Links between rock art and oral performance are often connected to practices of orality, especially for the transfer of information beyond human memory.

Keywords: rock art, language, graphic communication systems, methodology

Résumé

Cette contribution adresse un aspect dans le débat sur les connexions entre les gravures rupestre et langue. Recherche en ce moment dans l'archéologie, linguistique et l'épigraphie reconsidère le rôle et le degré de la communication dans les sociétés préhistoriques. Le modèle de communication du mathématicien, ingénieur électrique, cryptographe, et le fondant de la théorie de l'information, Claude Shannon (1916-2001), est peut-être une cadre utile pour les études scientifiques d'les gravures rupestres. Si les propositions de Claude Shannon est utilisé comme un modèle de données, au lieu d'un modèle théorétique, cela ouvre plus de possibilités analytiques, par ce que c'est n'est pas dépendant que les images fonctionnées comme un système de communication dans les temps préhistoriques.

Mots-clés : art rupestre, langage, systèmes de communication graphique, méthodologie

1. Towards a more nuanced definition of language

One might characterize language as a linear phenomenon of elements separated by pauses, glued together using a syntax. However, languages can take many forms besides those we are most familiar with; speech and writing. A broad division exists between natural and artificial languages. Natural languages can be either oral or graphic, whilst artificial languages can take more abstract form.

1.1 Claude Shannon's definition of language

In the 1940's, mathematician, electrical engineer, cryptographer, and founder of the field of information theory, Claude Shannon, proposed a very abstract definition of language: a statistical phenomenon, whose components are defined according to a set of quantifiable probabilities, determined by the statistical structure of language, including rules of combination and order, i.e. syntax or grammar (Shannon 1945, p. 11; 1948, p. 11; 1951, p. 50; Shannon , Weaver 1949). The definition is bound to the concepts of information and communication. Shannon emphasises that information is not equivalent to meaning. In the context of the topic of rock art and language, this is important, as rock art researchers have argued that rock art must have semantic meaning if linguistic methods are to be used justifiably.

1.2 Shannon's sender:message:receiver (SMR) data model of communication and the study of rock art

Based upon his definition of language, Shannon made a proposal for a generalized data model of a communication system (Fig. 1), which was developed subsequently by the linguist Roman Jakobsen (Fig. 2). In Jakobsen's development of Shannon's SMR model, messages are communicated in a specific context, in a given media, using a code. In this context, a code is defined as something which stands for something else.

* PhD Student, Department of Archaeology and Heritage Studies, Aarhus University, Denmark. Email: james.dodd@cas.au.dk

It is arguable that rock art possesses all the attributes of Shannon and Jakobson's models of communication. Viewed from an abstract perspective, one can view in the images as a code, communication within an anthropogenic, natural and cultural context. The creators of the images can be considered 'senders', and the audience 'receivers'.

1.3 Influence and legacy of Shannon's work

Shannon's ideas have been highly influential and remain relevant to the present day, as scholars in a variety of different fields realized that the generalized principles of linguistic analysis (as understood in the Saussaurian perspective) might be applied to the study of all kinds of communication systems or behaviour (Gardin 1992, p. 89). Arguably one of the most remarkable, if not important, results of Shannon's work was its contribution to the development of the structuralist movement in 1940's wartime New York, with the author's unpublished research having unearthed connections between Shannon and the linguist Roman Jakobson, and, thereby, the anthropologist Claude Lévi-Strauss. However, the details of this fascinating story must be told elsewhere.

2. Understanding the differences between data models and theoretical models

The utility of Shannon's proposals hinges upon an understanding of the difference between data models and theoretical models. As Read (2008, p. 1) states "there is a distinction between the data model derived from patterned observation and the theoretical models which produce patterned observations". In other words, there is distinction between using language as a theoretical explanation for the interpretation, function and use of rock art, and choosing to use Shannon's model, or any other linguistic model of communication, to analyse rock art.

By distinguishing between theoretical and methodological applications of language in the study of rock art, one recognizes that analysis and overall interpretation should be demarcated as far as possible (Meijer , Dodd 2018, p. 290). This allows the potential insights offered by linguistics methods to be explored whilst at the same time avoiding problematic assumptions, which include: the images must have meaning, one must be able to read rock art, and that rock art is a form of writing. The connection, or lack of any connection, with writing is particularly controversial. Some scholars have suggested that rock art, and other kinds of prehistoric art, may be a form of proto-writing (Anati 2017a; 2017b) Others are categoric that rock art is not writing, but may be one of the steps on the way toward writing (Petzinger 2016). Assumptions such as these can lead to the formation of axioms compromising critical evaluation of the evidence.

Of course, approaching everything from the abstract perspective of a data model is not entirely objective. The selection of samples and the strategies used to organize data during the analytical process is always informed by an element of theory (Moberg 1976, p. 3).

3. Studying rock art as a communication system from a structuralist perspective

Let us delve a little further into the detail of how one might use Shannon's SMR model, and its derivatives, to investigate the underlying significance of rock art.

3.1 Applying Shannon's definition of language, the SMR model of communication to rock art

An understanding of rock art based on the SMR model of communication might be used to find out something about the underlying significance of the images, whatever that may be, based on the structure of relations between the images and the contexts in which they are found. If we take Shannon's SMR model as a starting point: the images can be seen as a 'message', communicated using a graphic code, whose 'meaning' is unknown and must be recovered using only the details of the images themselves (including their context). At first sight, such a task might seem impossible, but this is not the case: Shannon's theory of communication expects that from the set of all possible messages, only some subset will be considered valid messages (Shannon 1945, p. 1; 1948, p. 1; Weaver 1949, p. 7; Sanderson 2020). In other words, even if the total number of possibilities is astronomically large, only a finite number of possible solutions are actually plausible. The size of each set depends on the specific characteristics of the rock art tradition that is the object of study, which will not be explored here.

A literal transcription is probably beyond our grasp for the rock art produced by non-literate societies during prehistory, where ethnography is unable to provide any kind of direct *a priori* information to assist investigations. However, even if we are unable to understand the contents of any message conveyed by the images, one can still infer something about its contents, as well as other kinds of information, such as how the system functions, based on the external characteristics of the message and any associated context.

3.2 Nordbladh's linguistic data model of rock art

In the 1970's Jarl Nordbladh, a Swedish archaeologist studying Southern Tradition rock carvings (refer Sognnes 2001, pp.12-14 for the spatial and chronological extents of this rock art tradition) at University of Gothenburg, Sweden, proposedly a data model of rock art based on the sender:message:receiver principle as part of his PhD (Fig. 3). It is immediately evident that images, their underlying referents and people, relate to one another in complex ways. There images relate spatially to one another in various ways in terms of where they occur: on the same or another surface. Similar signs and similar combinations thereof are repeated. Relations, or mappings, exist between the images and the underlying significance of the images. In Nordbladh's model, the interlocutors and the audience, (the senders and receivers) both share the same frame of reference, allowing them to understand the meaning of the images. As researchers, we effectively sit in the same position as the intended receiver, but lack knowledge of the necessary underlying informa-

tion (important for reasons which will become clear at the end of the section).
The presence of mappings is crucial if a rock art is to be studied using a data model based on language. Even in rock art traditions such as those of Samburu warriors, Northern Kenya, where a recent study suggests that the images have no meaning in a conventional semantic sense (Goldhahn et al. 2020, pp. 8, 14), mappings to some piece of information are nevertheless present (unintentionally). Within the contemporary rock art tradition of the Samburu, the images stand for something: an animal the creator encountered, or a story about a particular event (*ibid*, p. 8). The images are also associated with very specific context, as they are only created during a particular time period of a warrior's life, mostly by male initiates preparing for *rite de passage* ceremonies (*ibid*, p. 5).

3.3 The roots of Nordbladh's approach and his findings
Nordbladh took a structuralist approach to the analysis of rock art, rooted in turn within the work of his supervisor, Professor Carl Axel Moberg, and, thereby, structuralist theory. Structuralism, or structuralist approach, is defined as "any theory or method in which a discipline or field of study is envisaged as comprising elements interrelated in systems and structures at various levels, the structures and the interrelations of their elements being regarded as more significant than the elements considered in isolation" (OED). As mentioned previously, Shannon and key actors in his network were formative in the development of structuralist theory. Moberg was connected to this network, as a result of connections to a number of French scholars, in particular Jean-Claude Gardin, and thereby to the work of Claude Levi-Strauss and André Leroi-Gourhan.
It was perhaps a result of these (probably indirect) connections that Nordbladh arrived at his model. At the time, the work of Leroi-Gourhan (Leroi-Gourhan 1964-65; 1965) had already demonstrated that regularities could be found in Palaeolithic art: certain figures, and combinations of figures predominate in specific locations within caves. Nordbladh applied the same principles and, similarly, found that what is represented in Southern Tradition rock art is far from random. From study of rock carvings in Kville, Western Sweden, and Uppland, Eastern Sweden, Nordbladh suggested that the figures only demonstrate a finite number of relations with one another. Namely, they are arranged in certain ways, exhibit a variety of different orientations, and can be connected to one another topographically, either directly (superimposition) or indirectly (in terms of their proximity to one another) (Nordbladh 1981, pp. G38-G39, pp. G78-G79). When Nordbladh considered all classifications of relations together, as combinations, Nordbladh found that specific combinations of the main figure categories (cup-mark, ship, anthropomorph, animal, foot-sole, cross-in-circle) predominated in his Swedish study areas, whilst are others occur more rarely, or are completely absent (Nordbladh 1980, pp. 62-63 Tables 14 and 15). Importantly, Nordbladh's findings conform to the expectations of Shannon's theory of communication, outlined in the previous subsection (valid messages$\subseteq$all possible messages). Thus, it would appear, at least in this case, that Southern Tradition rock art, appears to exhibit traits conforming to Shannon's definition of language, thereby supporting the idea of studying rock art as a data model. This conclusion does not mean to imply that rock art is a natural language, although subsequent scholarship may be able to confirm or reject such a notion. Instead, it suggests that it should be possible to study rock art using linguistic methods in order to gain new levels of insight into the underlying significance of the images.
Whilst the exact details of the methodology are too complex to discuss in detail here, one might be able to exploit the structure of the SMR model, as developed by Nordbladh to work backwards from the images to gain greater levels of insight into one or more of: the underlying significance, role and use of the images. Finding an unknown using only observation of the outcomes and/or piecing incomplete fragmentary information together in order to arrive at some kind of conclusion is not a problem exclusively found in rock research, or archaeology. One group facing similar problems can be found in the field of cryptanalysis: "the analysis and decryption of encrypted text or information without prior knowledge" of the procedure for encoding (OED).

4. Graphic codes: a theoretical framework
Let us now move on to consider how Shannon's model, and its derivatives, operative in practice. Our own cultural preconditioning makes it difficult for us to imagine a society without writing (Clarysse , Vandorpe 2008, p. 715). Just like language, many kinds of information technologies exist besides those which immediately come to mind; speech and writing. Non-literate societies are far more reliant on oral and visual methods of communication for the transfer and preservation of knowledge (Leroi-Gourhan 1993, pp. 257-266; Couch 1989, p. 587). In the case of visual methods, graphic codes are used. Given previous discussions concerning Shannon's definition of language and his SMR data model of communication (including derivatives), it is immediately evident that rock art can be considered a graphic code. However, rock art is just one kind of visual communication.

4.1 Rock art as a graphic communication system
In current literature, a more nuanced understanding of visual communication and what constitutes a graphic code is emerging. Traditionally, the study of graphic codes has been very much focused on the question of what does or does not constitute writing (Mikulska 2020, p. 6). In response to this this debate, the term graphic communication system has entered into use, with it being suggested that "we ought to drop the label 'true writing' and maintain a straightforward distinction between glottographic (both phonologically

and nonphonologically based) and semasiographic (non-language-utterance-based) sign system[s]" (Urton 2003, p. 28 in Mikulska 2020, p. 8).

4.2 Four types of graphic code: the typology of Morin, Kelly and Winters

Recently, Morin et al (2020) made a proposal for the principal differences between the main kinds of graphic code. With reference to examples from contemporary society and ethnography, Morin et al. propose four main types exist: emblems, specialized notations, speech bound notations and writing. A given system may belong to more than one category simultaneously. For example, consider Australian message sticks (*ibid*, p. 732).

The distinctions between each of the four types hinge upon what Morin et al. term the productivity of the code, and whether or not additional knowledge of language is necessary to use the code. Productivity is related to the idea that codes have an information carrying capacity (*ibid*, p. 729), which is related to the concepts of entropy and redundancy within language – first described and quantified by Shannon (1948; 1951). Entropy is a statistical parameter borrowed from thermodynamics, used to measure the amount of information produced on average for each constituent part of a language, which can, in turn, be used to quantify the information capacity of a system. The concept of redundancy, describes "the amount of constraint imposed on a text in language due to its statistical structure" (Shannon 1951, p. 50). The overall combined effects of entropy and redundancy are the reason why one can state that only subset of all possible messages can be considered valid messages. Mathematical proofs of this phenomena can be followed in the references (Shannon 1948, pp. 10-14; Weaver 1949, p. 12; Shannon 1951). For our purposes, it is sufficient to state that the characteristics of graphic codes dictate their carrying capacity, which is scalable. Essentially, the number of potential outcomes and whether or not they can be meaningfully combined mean that certain graphic codes are very flexible, whilst others are not. The number of symbols which need to be memorized is also important: more symbols can be very specific semantically, but take longer to learn, and can be cumbersome as a system (Robinson 2007, p. 40). One of the reasons writing using an alphabet and the Latin script is so successful is the flexibility of the system to express anything one can describe using words (Morin et al. 2020, p. 735).

It easier to see how productivity and speech-boundedness affect graphic codes if we consider each of Morin et al.'s types in more detail in conjunction with some practical examples.

4.3 Emblems

Emblems, such as the international code of signals for ships, traffic signs, family heraldry and clan totems are language independent, but have a low productivity. The meaning of each symbol is often standalone, and the possibility to create a string of information, is limited (Morin et al. 2020, p. 733). If we take the example of a Haida totem pole, on the Northwest coast of Canada, each emblem represents the identity of an individual or group (Hamilton 2015). Several studies worldwide have suggested a totemic significance for certain scenes and traditions in rock art (for example Fuglestvedt 2008; 2010).

4.4 Specialized notations

This category of code can be understood independent of language and is highly productive. Examples include mathematical symbols, and Andean Khipu: knotted cords, sometimes coloured, used for the recording of numerical and non-numerical information (Urton 2003; Medrano , Urton 2018).

4.5 Speech bound notations

Rock art, as well as many other kinds of prehistoric art found on other media, found worldwide often manifests itself as a speech bound notation (Arsenault 2004; Arsenault , Zawadzka 2013; Keyser , Klassen 2001; May et al. 2019). This type of graphic code is language dependant as it requires additional oral elaboration in order to be understood (Morin et al. 2020, pp. 731, 734). Such codes are form part of a wider suite of oral practices (Couch 1989, pp. 587-588), collectively referred to as orality (the quality of being verbally communicated (OED)). Speech bound notations frequently function as mnemonics for oral performance involving the recollection of information, which can be of an esoteric character (Kelly 2015, p. 12, pp. 63-69). Knowledge of such information can be subject various levels of control, through secret societies (Hayden 2018, pp. 1-26). Sometimes, a person in the community is appointed responsible for memorizing and reciting such information (Green , Emil Her Many Horses 2005). Whilst general conventions can exist, speech bound notations are often poorly standardised: due to the individual retaining a certain freedom of expression (Morin et al. 2020, p. 734).

The graphic communication systems of the indigenous societies of the Northwest Plains of North America of the Late Prehistoric (250 AD-1700 AD), Protohistoric (1700-1840 AD) and Historic (1840-1900) Periods, provide a range of examples of some of the many forms speech bound notations can take, and attest the variety of media they can be found upon. Work by Keyser and Klassen has used historic ethnography and contemporary indigenous knowledge of graphic codes found on perishable media as an analogy for the study of contemporary rock art. (Keyser , Klassen 2001, pp. 32-37).

Two, partially chronologically overlapping rock art traditions are found on the Northwest Plains of North America: The Ceremonial and Biographical Traditions. The two traditions differ from one another in terms of their appearance and subject matter. The Ceremonial Tradition predates European contact and is associated with the spirit world, in particular vision quests (Keyser , Klassen 2001, p. 161). Vision quests involve retreating to a specific location in the landscape where spiritual power is believed to be more concentrated in

order to fast and pray (*ibid*, pp. 38, 191). Such places are often situated at dramatic locations in nature, for example, the Hoodoos, at Writing-On-Stone, Alberta, Canada (*ibid*, pp. 36-37).
Where the purpose of the vision quest was a coming of age ritual (usually for young men) the symbol which appeared during the vision became the guardian spirit for that person throughout life, appearing as a mark of identity on personal items such as shields and tipis (*ibid*, pp. 38, 191). Rock art was often created at the sacred place where the vision was received, representing and commemorating the details of the vision. Over time, the images themselves could acquire their own power of their own, indicating a place where spirits dwelled (*ibid*, pp. 38-39).
Biographical tradition rock art begins later than that of the Ceremonial Tradition, and is associated with the profane world, usually recording deeds and events "of another person, or a person and their friends" (Keyser 2020). One of the interesting features of this graphic communication system is that the same or similar visual conventions are used across a range of different context and media, including: rock art (Keyser , Klassen 2001, Fig. 15.6), robe (Green , Emil Her Many Horses 2005) and ledger art (*Plains Indian Ledger Art Project. [online]*). Given that the end of the tradition overlaps with historical accounts, literal transcriptions are available, permitting the detailed analogies between different media, including rock art (Keyser 1996; Keyser , Klassen 2001, p. 259).

4.6 Writing
In Morin et al.'s typology, writing is seen as a special category of language dependent graphic code, encoding morphemes or phonemes found in natural language in the form of glyphs (e.g. Chinese) or a script (e.g. Latin alphabet) (Morin et al. 2020, p. 729 after Sampson 1985). Morin et al. consider the defining attribute of writing to be its high productivity: great flexibility of expression and high rate of compression, which is in contrast to the more limited information carrying capacity of, say, a speech bound notation (Morin et al. 2020, pp. 729-730, 735; Kelly et al. 2020, p. 5).

5. Conclusion: rock art and language
It is argued here that the many of the key ideas suggested in the 1940's by the pioneer of information theory, Claude Shannon, may provide some useful theoretical and methodological perspectives for the study of rock art. By adopting a more abstract view of language, as any stochastic process which produces a series of discreet symbols according to some system of probabilities (Shannon 1945, p. 11), it is possible to construct data models based on Shannon's sender:message:receiver model of communication in order to investigate a specific set of problems within rock art research using linguistic methodologies. These problems pertain to the underlying significance of the images and ascertaining if any rules of combination and order exist governing the use of the system. It is evident that rock art possesses all of the key attributes of Shannon's definition of language, his theory of communication and sender:message:receiver (SMR) model. In an SMR data model applied to rock art, the images function as a graphic code.
Fundamental to the viewpoints expressed in this contribution is an awareness of the difference between data models and theoretical models, as outlined by Read (2008). The distinction allows researchers to avoid pitfalls associated with a theoretical perspective: where rock art is assumed from the outset to be a language. In a data model, language provides a methodology to analyse the images. Interpretation of the findings is a separate issue.
With reference to developments of Shannon's model by the linguist Roman Jakobson, and the Swedish archaeologist Jarl Nordbladh, who devised a linguistic data model of rock art based around the sender:message:receiver principle in the 1970's, it is argued that a structuralist perspective can be used to find out more about the underlying significance of the images, based on study of the relations between the figures and the contexts in which they are found.
In the latter half of the article, we have considered the place of rock art as one of many kinds of graphic code. It is contended that the recently proposed typology outlined by Morin et al. (2020) provides a useful framework for classifying graphic codes and understanding the principal differences. Based on whether or not use of the code depends on knowledge of the language associated with it, and the code's carrying capacity for information (termed by Morin et al. as productivity), Morin et al. identify four groups: emblems, specialized notations, speech-bound notations and writing. Whilst emblems can be connected to rock art with a totemic significance, speech bound notations function as an information technology connected to orality: acting as mnemonics for the recording, performance and transfer of various kinds of information.

Note
This contribution is based on a chapter of the author's forthcoming PhD thesis (Dodd in prep. 2021), where many of the ideas and concepts summarized here are examined in more detail.

Bibliography

Anati, E.
2017a *Decoding Palaeolithic Engravings On Bone*, in «Expression», 16, pp. 9-23.
2017b *Editorial Notes. The Message behind the Image*, in «Expression», pp. 2-3.
Arsenault, D.
2004 *From natural settings to spiritual places in the Algonkian sacred landscape: an archaeological, ethnohistorical and ethnographic analysis of Canadian Shield rock-art sites*, in Arsenault, D., Chippindale, C., Nash, G. (eds.), *The Figured Landscapes of Rock-Art: Looking at Pictures in Place*, Cambridge, Cambridge University Press, pp. 289-317.
Arsenault, D., Zawadzka, D.
2013 *Spiritual Places: Canadian Shield Rock Art Within Its Sacred Landscape*, in Breen Murray, W., Greer, M., Helene Hayward, M., Gillette, D.L. (eds.), *Rock Art and Sacred Landscapes One World Archaeology*, New York, NY, Springer New York, pp. 117-137.
Clarysse, W., Vandorpe, K.
2008 *Information technologies: writing, book production, and the role of literacy*, in Oleson, J.P. (ed.) *Engineering and Technology in the Classical World*, Oxford ; New York, Oxford University Press, pp. 715-739.
Couch, C.J.
1989 *Oral Technologies: A Cornerstone of Ancient Civilizations?*, in «The Sociological Quarterly», 30(4), pp. 587-602.
Dodd, J.
in prep. 2021 *Signs, Structure and Cryptanalysis*. PhD Dissertation, Department of Archaeology and Heritage Studies, Aarhus University.
Fuglestvedt, I.
2008 *How many Totemic Clans existed in Eastern Norway during the Late Mesolithic?*, in Chilidis, K., Lund, J., Prescott, C. (eds.), *Facets of Archeology. Essays in Honour of Lotte Hedeager on her 60th Birthday. OAS nr. 10*, Oslo, Universitetet i Oslo Arkeologisk Skrifter, pp. 351-366.
2010 *Animals, Churingas and Rock Art in Late Mesolithic Northern Scandinavia*, in Goldhahn, J., Fuglestvedt, I., Jones, A. (eds.), *Changing Pictures: Rock Art Traditions and Visions in the Northernmost Europe*, Oxford, Oxbow, pp. 23-34.
Gardin, J.-C.
1992 *Semiotic Trends in Archaeology*, in Gardin, J.-C., Peebles, C.S. (eds.), *Representations in archaeology*, Bloomington, Indiana University Press, pp. 87-103.
Goldhahn, J., Labarakwe, S.L., Skoglund, P., Westergren, E.
2020 *'I Have Done Hundreds of Rock Paintings': On the Ongoing Rock Art Tradition among Samburu, Northern Kenya*, in «Cambridge Archaeological Journal», pp. 1-18.
Green, C., Emil Her Many Horses
2005 *Lakota Winter Counts*. Available at: https://www.si.edu/object/lakota-winter-counts:yt_XNaYrAKiZmw (Accessed: 1/3 2021).
Hamilton, K.D.
2015 *Haida Totem Poles: Reflections of a Society*, in «BCSP» 39, pp. 27-41.
Hayden, B.
2018 *The Power of Ritual in Prehistory: Secret Societies and Origins of Social Complexity*. Cambridge, Cambridge University Press.
Jakobson, R.
1960 *Closing Statement: Linguistics and Poetics*, in Sebeok, T.A. (ed.) *Style in Language*, Cambridge, Mass, pp.
Kelly, L.
2015 *Knowledge and Power in Prehistoric Societies: Orality, Memory and the Transmission of Culture*. Cambridge, Cambridge University Press.
Kelly, P., Winters, J., Miton, H., Morin, O.
2020 *The predictable evolution of letter shapes: An emergent script of West Africa recapitulates historical change in writing systems*, in «Current Anthropology», pp. 1-38.
Keyser, J.D.
1996 *Painted bison robes: the missing link in the biographic art style lexicon*, in «Plains Anthropologist», 41(155), pp. 29-52.
2020 *The Cut Bank Archaeology Project. ARARA online lecture series on August 8, 2020*. Available at: https://www.youtube.com/watch?v=nZS5wxXpuHg (Accessed: 15/3/ 2021).
Keyser, J.D., Klassen, M.A.
2001 *Plains Indian Rock Art*. Seattle and London, University of Washington Press.
Leroi-Gourhan, A.
1964-65 *Le geste et la parole. Sciences d'aujourd'hui*. Paris, Albin Michel.
1965 *Préhistoire de l'art occidental. L'art et les grandes civilisations*. Paris, Lucien Mazenod.
1993 *Gesture and speech. An October book*. Cambridge, Mass, MIT Press.
May, S.K., Maralngurra, J.G., Johnston, I.G., Goldhahn, J., Lee, J., O'Loughlin, G., May, K., Nabobbob, C.N., Garde, M., Taçon, P.S.C.
2019 *'This is my father's painting': a first-hand account of the creation of the most iconic rock art in Kakadu National Park in «Rock Art Research»*, 36(2), pp. 199-213.
Medrano, M., Urton, G.
2018 *Toward the Decipherment of a Set of Mid-Colonial Khipus from the Santa Valley, Coastal Peru*, in «Ethnohistory», 65(1), pp. 1-23.
Meijer, E., Dodd, J.
2018 *Towards a new era of rock art documentation*, in Meijer, E., Dodd, J. (eds.), *Giving the Past a Future. Essays in Archaeology and Rock Art Studies in Honour of Dr. Phil. h.c. Gerhard Milstreu. Access Archaeology*, Oxford, Oxford, pp. 287-299.
Mikulska, K.
2020 *Introduction. Indigenous Graphic Communication Systems: A Theoretical Approach*, in Mikulska, K., Offner, J.A. (eds.), *Indigenous Graphic Communication Systems A Theoretical Approach*, University Press of Colorado, pp. 3-22.
Moberg, C.-A.
1976 *"Structureville" ; a young person's guide to find analysis*. Göteborg, Göteborgs Universitet, Institutionen för arkeologi särskilt nordeuropeisk.
Morin, O., Kelly, P., Winters, J.
2020 *Writing, Graphic Codes, and Asynchronous Communication*, in «Topics in cognitive science», 12(2), pp. 727-743.
Nordbladh, J.
1978a *Images as Messages in Society. Prolegomena to the Study of Scandinavian Petroglyphs and Semiotics*, in Kristiansen, K., Paludan-Müller, C. (eds.), *New Directions in Scandinavian Archaeology. Studies in Prehistory and Early History 1*, Copenhagen, The National Museum of Denmark, pp. 63-78.
1978b *Some problems concerning the relation between rock art, religion and society*, in Marstrander, S. (ed.) *Acts of the International Symposium on Rock Art. Lectures at Hankø 6-12 August, 1972.*, Oslo, Universitetsforlaget, pp. 185-210.
1980 *Glyfer och rum kring hällristningar i Kville. Akademisk avhandling, utgiven vid Institutionen för arkeologi, Göteborgs universitet.*, Göteborg.
1981 *Knowledge and Information in Swedish Petroglyph Documentation*, in Moberg, C.-A. (ed.) *Similar finds? Similar interpretations? : Glastonbury - Gothenburg - Gotland : nine essays*, Göteborg, Göteborgs Universitet. Institutionen för arkeologi, pp. G1-79.
OED
Oxford English Dictionary. Oxford University Press.
Petzinger, G.V.
2016 *The first signs : unlocking the mysteries of the world's oldest symbols*. First Atria Books hardcover edition. edn, New York, Atria Books.
Plains Indian Ledger Art Project. [online]. Available at: https://plainsledgerart.org (Accessed: 1/3/ 2021).
Read, D.W.
2008 *A Formal Explanation of Formal Explanation*, in «Structure and Dynamics: eJournal of Anthropological and Related Sciences», 3(2. Article 4.), pp.
Robinson, A.
2007 *The Origins of Writing*, in Crowley, D.J., Paul, H. (eds.), *Communication in history : technology, culture, society*, Boston, Pearson Allyn & Bacon, pp. 36-42.
Sampson, G.
1985 *Writing Systems: A Linguistic Introduction*. Stanford, Stanford University Press.
Sanderson, G.
2020 *Hamming codes, how to overcome noise. Part 1*. Available at: https://youtu.be/X8jsijhllIA?t=196 (Accessed: 7/9 2020).

Shannon, C.E.
1945 *A Mathematical Theory of Cryptography*, Alcatel-Lucent, Available at: https://www.iacr.org/museum/shannon/shannon45.pdf.
1948 A Mathematical Theory of Communication. Reprinted with corrections., in «The Bell System Technical Journal», pp. 379–423, 623–656.
1951 Prediction and entropy of printed English, in «The Bell System Technical Journal», 30(1), pp. 50-64.
Shannon, C.E., Weaver, W. (eds.)
1949 *The Mathematical Theory of Communication*. Urbana, Illinois, The University of Illinois Press.
Sognnes, K.
2001 *Prehistoric imagery and landscapes. Rock art in Stjørdal, Trøndelag, Norway*. Oxford, BAR International Series 998.
Urton, G.
2003 *Signs of the Inka Khipu: Binary Coding in the Andean Knotted-String Records*. Austin, University of Texas Press.
Weaver, W.
1949 Recent Contributions to the Mathematical Theory of Communication, in Shannon, C.E., Weaver, W. (eds.), *The Mathematical Theory of Communication*, Urbana, Illinois, The University of Illinois Press, pp. 1-28.

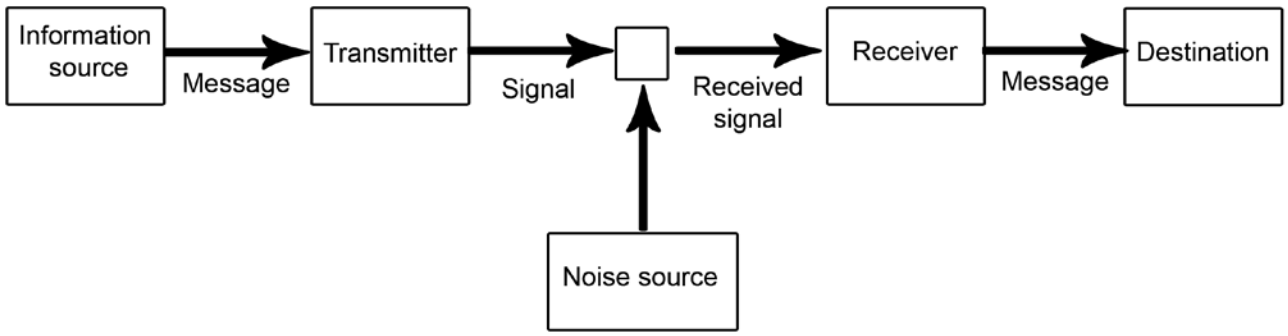

Fig. 1 – Shannon's "Schematic diagram of a general communication system" (Illustration: author, after SHANNON 1948: FIG. 1)

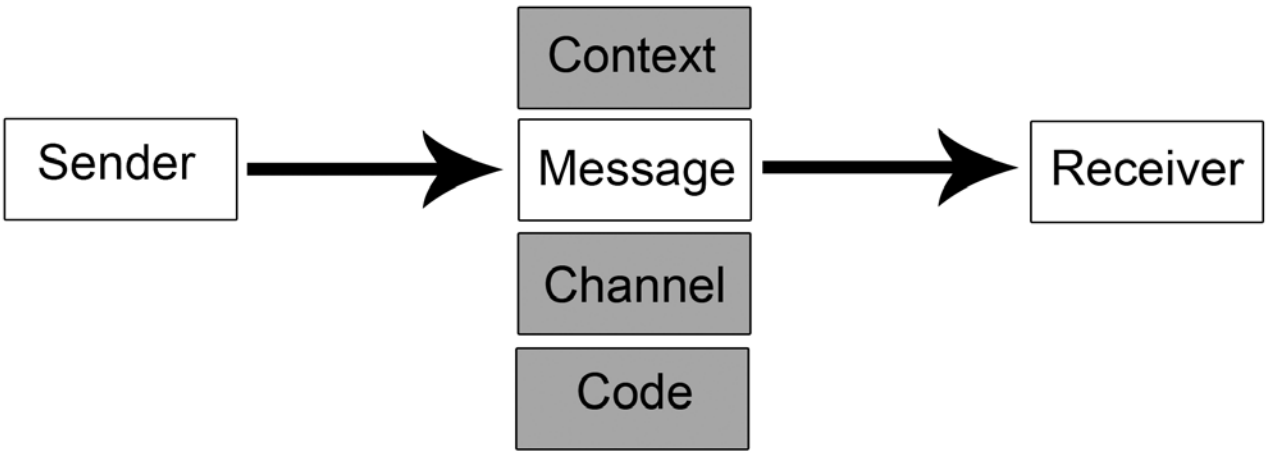

Fig. 2 – Roman Jakobson's functions of language (JAKOBSON 1960, p. 353). (Illustration: author).

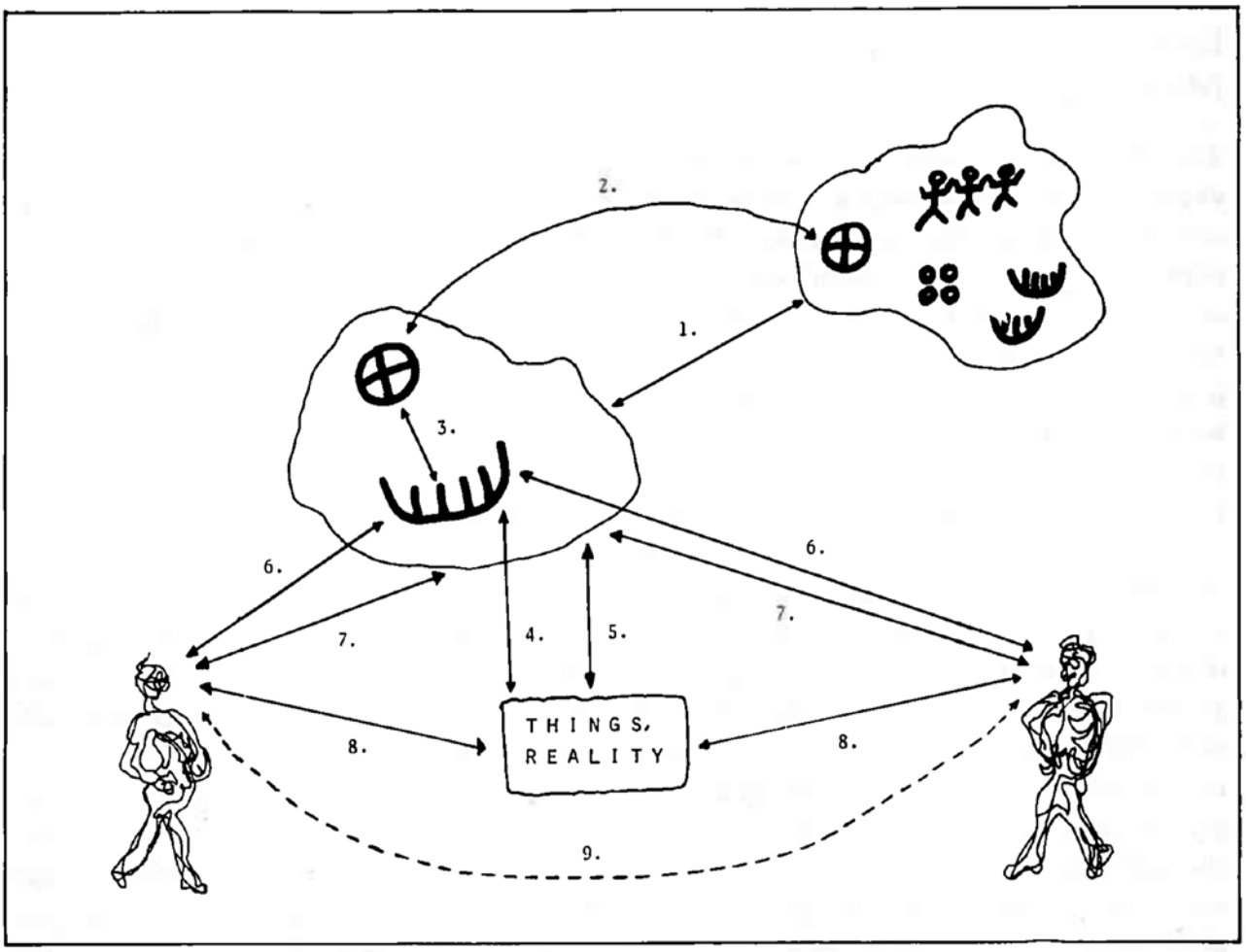

Fig. 2. A simplified linguistic model applied to the petroglyphs.

1–3 Syntactic studies:
1) between picture frames
2) between signs of different picture frames
3) between signs inside a single picture frame

4–5 Semantic studies:
4) between sign and thing (= image)
5) between message-contents and reality

6–8 Pragmatic studies:
6) between user and image
7) between user and message
8) between user and reality, inclusive things.

If 1–8, communication, 9, is possible.

Fig. 3 - Nordbladh's simplified linguistic model of rock art as a communication system. (Nordbladh 1978a, Fig. 2; Nordbladh 1978b, Fig. 5)