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Can we use Pictograms in a Long Term Communication System Related to a Radioactive Waste Repository? – 18301

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ABSTRACT

Pictograms are often mentioned as a possible tool for sending messages about radioactive waste repositories in a far future, when the understand ability of our languages will have been lost. But they have also limits, related to the use of conventions that may fade over time.

The goals of a signaling system for the long term may be (1) to alert (raise attention), (2) to inform of an underlying danger due to the existence of radioactive wastes, (3) to induce a favorable behavior (provoke or deter actions) in order not to disturb the performance of the repository.

The quest for trans-cultural and trans-generational performance requires that some universal semiotic features be identified, shared by human beings of various cultures nowadays, and from far in the past to the present.

Considering the typology of colors in various languages, the use of colors in ancient rock art and in children's drawings, a dedicated role may be assigned to each of the three colors, white, black and red/ocher, with a high potential for sustainable meaning:

- 1) red background = pay attention to this object because of the simple presence of the red color, that is to say the first color felt as color;
- 2) white inscription = absence of the objet / action represented;
- 3) black inscription = presence of the objet / action represented.

The representation of a human body in movement inside a context is also understandable by people from various cultures.

The combination of these "semiotic primitives », used as relevant semantic features of the object and/or the experience to be represented, and "toposensitive" criteria, used for pictogram production processes, would thus become a way to conceive a trans-cultural and transgenerational sign system for the signaling of radioactive danger.

The choice of the stone could guarantee the durability of the support; the color could guarantee its visibility; and both could guarantee the transmission of the message.

Combining these criteria could open the way to a long term communication system about radioactive waste repositories.

INTRODUCTION

Andra's Memory Program

Andra launched in 2010 the Memory Program, to consolidate the provisions for knowledge and memory preservation already implemented on existing radioactive waste repositories and extend their durability to millennia, namely in the view of projects for new repositories.

This multifaceted program [1] includes archival work, societal interactions, academic studies and international cooperation. The archival work is devoted at selecting the documents deemed necessary for permanent storage, organizing them and helping the search and interpretation, in accordance with regulatory requirements. The societal interactions, such as artistic contests and working groups with local stakeholders, aim at fostering the transmission of the awareness of radioactive wastes repositories by the society, while enriching Andra's approach for memory preservation. A variety of academic studies is also conducted, in scientific fields such as materials science, landscape archeology or semiotics. The objective of these studies is to enlighten the avenues for enhanced robustness and extended duration of memory preservation. Involvement of Andra in international cooperation aims at sharing experience and knowledge and mutualizing efforts, as is generally the case for any subject, but also at building, above the local and national layers of memory provisions, an international layer for enhanced robustness. In this respect, Andra is an active participant of the Records Knowledge and Memory preservation initiative (RK&M) coordinated by the Nuclear Energy Agency of OECD [2].

Semiotics, beyond Linguistics

Among the fields of academic research, Semiotics, beyond Linguistics, has been identified as a major subject to be investigated. Preliminary work was performed in 2013-2014 by the Semiotic Research Center (CeReS) of Limoges University: two focused studies were conducted along two lines: on "durability/longevity" of media and languages, and secondly on "mediatizing/mediatization", i.e. accessibility, sharing, exploitation of the message [3].

The durability/longevity study, based on literature survey (e.g.: [5],[6],[7],[8],[9]) showed that neither a language, nor several languages, nor images (pictograms) or even a material specific to a support media (e.g. a sapphire disk) are a guarantee of longevity of a message. It is better to rely on a set of devices, forming a meaningful whole, to be transmitted by tradition routes. The mediatizing/mediatization study showed that not only they cannot guarantee transmission, but they cannot guarantee appropriation either.

Based on this preliminary work, a cooperative research program has been launched by Andra and CeReS since 2015, with the aim of setting bases for a long-term communication system. This program includes the research work of two PhD students and contributions of research professors from or associated with the CeReS.

The limits of pictograms

Pictograms are often mentioned as a possible tool for sending messages about radioactive waste repositories in a far future, when the understand ability of our languages will have been lost. In present world, they are increasingly used, as signs in public places or for furniture mounting instructions, for example. Their ability to be understood by people speaking different languages would be a promise for their understand ability over millennia. But pictograms may also show drawbacks, as mentioned above. Understanding their limits is essential for an adequate implementation of a semiotic system where they would be used.

Even if they are less sensitive than languages to previous learning, pictograms also refer to a cultural background.

For example, a survey carried out in the Cameroon cotton belt on farmer's understanding of pesticide pictograms elaborated by the Food and Agriculture Organization of the United Nations (FAO) [4].showed that many of the pictograms were either not understood or even misinterpreted. In fact, there was a multitude of incorrect and dangerous replies for all of the pictograms such as: "this product may be used to feed fishes" for a pictogram aiming at preventing from spreading the pesticide in water (see pictogram n°13 in Fig. 1) or "this product is to be poured onto the seeds" for a pictogram aiming at showing how the pesticide should be handled at the dry stage (pictogram n°2). Another example is the skull and bones (pictogram n°

11), which was not understood at all by 43 % of the farmers in the survey, while erroneously interpreted by 17.5 %, and correctly interpreted by only 39.5 %. This survey shows how pictograms elaborated in a given context, in this case the occidental culture, may incorporate unwittingly codes and conventions unknown in other cultures.

In other words, understanding correctly a pictogram requires a common cultural background for the author and the reader. In fact, pictograms most often remind us of some knowledge previously learnt. For example, the red triangle used worldwide to alert car drivers of specific dangers is very efficient in doing so, at a glance, because its meaning has been explained before.

Furthermore, the way pictograms are organized for a proper reading is also influenced by cultural aspects. For example, reading from left to right is the normal way for readers of English, but not for readers of Arabic. It is therefore necessary to induce a direction for reading from the communication system itself.



Figure 1: Pesticide pictograms used in the interpretation survey [4]

DEFINING PRELIMINARY FEATURES FOR LONG TERM PICTOGRAMS

As Pascal Vaillant shows [12], the communicative power of a pictogram depends on the relation established between the sign and the object: the modality of representation consists in grasping certain characteristics of the object represented so as to be understandable by a certain impregnated community of a certain culture at a certain time.

Following Umberto Eco's [6] semiotic theory, the construction of a pictogram is done in two stages: the first concerns the identification of the relevant features on which the representation of the object is based in a specific culture; the second concerns the methods of graphic transcription of the relevant features chosen on a given support. So, during the two phases it is necessary to choose between 1) staying closer to the object by keeping a motivational link between the representation of the object and the object itself, or 2) staying closer to the system within which the sign fits, by establishing a convention link that allows the cultural dimension to take over in the process of constructing the pictogram.

In order to give a trans-cultural and trans-generational character to the system of signs to be conceived, and in order to answer to the necessity of "durability/longevity" of media and languages, it is then necessary to be able to keep a strong link of motivation between the object and / or the experience to be represented and its representation. And for this, it is necessary to identify "semiotic universals" stemming from the elementary experiences, that is to say universal experiences shared by all members of the human species. On these "semiotic universals" we can build the link of motivation governing the relation of representation between the object and / or the experience and the pictogram referring to it.

Eco distinguishes between the genesis of a sign by "ratio facilis" (when it is part of a system already standardized by the use within a community) and by "ratio difficilis" (when it does not fit into a standardized system). By taking up this distinction, we can consider two possible cases of production and / or use of pictograms: in the first case, the inscription in a specific cultural context allows the users to interpret it easily by recalling the set of relations that it maintains with the other pictograms present in the system; in the second case, its interpretation does not depend on the other pictograms already used for several possible reasons (for example, referring to an unknown object and / or experiment), which supposes that one must look for the key of interpretation in the relation between the elements composing the plane of the content and the elements composing the plane of the expression of the sign (link of motivation). In other words, for a pictogram to be easily interpreted independently of the system used in a particular cultural context, the link of motivation should be reinforced despite the convention link.

The hypothesis proposed to design pictograms understandable by any community (trans-cultural) at any time (trans-generation) is the following one: drawing on the different cultures, it would be necessary to identify general semantic features (the "semiotic universals") because of the fact that they can be recognized as common to all human experience, as for example any experience referring to the "anatomical body" of which every user is endowed as belonging to the same human species. Once identified, these "semiotic universals" would in principle provide the motivational link looked for to construct signs (pictograms) interpretable independently of any particular culture and at any time.

For example, the possibility of basing the motivational link on micro-processes determined by human physiology, as moving in space all around him (with the legs, arms, head, etc.) and respecting the constraints and exploiting the possibilities given by the physiology of the "anatomical body" common to all men as members of the same human race, constitutes an elementary semantic model of organizing space in the immediately proximate environment. Thus, this elementary semantic model let to identify "universal" semantic features, by providing "semantic primitives" that can be found in different languages [13, 14].

This link of motivation leads to an "isomorphism" between the content plan and the expression plan [10]. The isomorphism is a structural feature: it concerns the link between the relative position of the elements composing two models, the perceptual model of the object and / or the experience to be represented (pictogram content plan) and the perceptual model of the graphical device of the sign (pictogram expression plan). According to Vaillant [12], the link relating the object (and / or experience) to the sign is based on

transformations having a spatial nature, as shown by the shift from the perceptual model of the object and / or experience first to the semantic model of mediation, finally to the perceptual model of the sign¹.

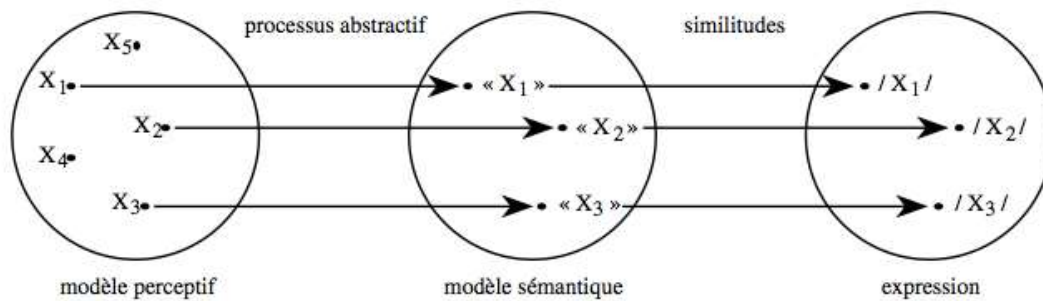


Figure 2: Transformations constituting the link relating an object to its related sign, according to Vaillant [12]

This hypothesis rests in particular on the spatial character of the semantic features retained to construct the graphic device of the pictogram. As Eco writes [6], a semantic feature is "toposensitive" when its meaning depends on its position and orientation in space. The direction of a signaling arrow is an elementary example of a toposensitive feature. Another example could also be related to the construction of the idea of plurality: several similar units in the same space mean « plural » by their toposensitive configuration. This property is fundamental to find a direct anchorage - and therefore an easily recognizable motivation link - between the perceptual model of the object and / or the experience and the perceptual model of the sign. The relative position of the different graphic elements, the place they occupy with respect to each other in any graphic device, confers a meaning on the whole formed by the elements composing the pictogram.

REQUIREMENTS FOR A TRANS-CULTURAL AND TRANS-GENERATIONAL SYSTEM OF PICTOGRAMS TO SIGNALIZE RADIOACTIVE DANGER

To create a system of pictograms, we have to define first its goals.

First goal: to alert

Since they are performative acts (Austin 1952 [15]), the mere presence of the marker must be able to achieve the primary goal: to attract attention. The warning pictograms do not all serve the same purpose: 1) they warn about the presence of a danger, thus showing the danger in question; 2) they warn about behavior to be held in case of danger, and this behavior can be of two kinds: obligation (do something) or prohibition (do not do something).

As shown by Tijus et al. (2001) [16], a system of pictograms can provide:

- indications of objects and/or properties of objects (first level of semantization)
- indications of action(s) and/or prohibition of action and/or cessation of action (second level of semantization)

¹ "This process, when establishing a *ratio difficilis*, goes from a *perceptual model* from which *recognition conventions* stabilize a *semantic model*. The creation of the iconic expression model, i.e. the establishment of the *transcription conventions*, depends on a number of *transformation rules* that make some of the properties of the continuum of the expression correspond to the properties of the semantic model » (translated from Vaillant [12], p. 40).

- indications of action(s) and/or prohibition of action and/or cessation of action on objects and/or categories of objects and/or properties of objects (third level of semantization) .

For a system of pictograms dedicated to report the danger, the object in question is the danger (or a particular aspect of it), and the actions are the behaviors to hold and/or to prohibit in case of danger.

Second goal: inform of the presence of a radioactive wastes repository

This goal is pursued by creating representative pictograms whose objective is to show the danger associated to the radioactive wastes. In fact, the representative pictogram is supposed to provide unambiguously enough physical evidence to directly evoke the object or situation represented².

One of the most frequent problems to conceive a system of pictograms concerns the ambiguity of the image constituting the pictogram: this image is often not legible without a prior learning because of its degree of culturalization, that is to say conventionality, or without an accompanying text that allows disambiguation.

For instance, the signs for "explosive", "oxidizing", "flammable" products play on three shades of the "fire" concept by using rather close symbols that appear as variations of the "flame". The concept of "flame" is therefore too vast for these three pictograms to be immediately comprehensible, that is to say without the mediation of the linguistic text. These pictograms can't show adequately the danger they've to represent.



Figure 3: Pictograms for “explosive”, “oxidizing” and “flammable” products: three shades of the “fire” concept

Concerning the use of pictograms identifying the presence of radiation, even with text embedded, the opacity of the symbol does not change for generations far away in the future.



Figure 4: The opacity of the radioactivity pictogram for remote generations

Third goal: to provoke or deter an action, by informing of the consequences of disturbing the repository

A pictogram to report a danger normally consists of behavioral pictograms that must induce to provoke and / or prohibit something. To assure its goal, the behavior represented must be clear.

² See TIJUS. C et al, [16] p. 6.

For instance, the pictogram provided by the new ISO standards is really difficult to read because of:

- the conventional character of the symbol identifying the radioactive hazard;
- the conventional character of the symbol identifying the mortal danger;
- the reading order valid only in the Western cultural world (from top to bottom, from left to right)³.



Figure 5: Cultural conventions in the ISO pictogram

STRUCTURE AND COMPONENTS OF A SYSTEM OF PICTOGRAMS

A signaling system is composed of three basic components: (1) the shape and the color of the support, (2) the pictogram(s) and (3) the context in which it works. These three elements have to be combined to assure the three goals mentioned above: to alert, to show the underlying danger, to provoke or deter an action.

First goal: using the support to alert

The form and the color of the support are good candidates for calling for attention (first objective).

Anthropologists Brent Berlin and Paul Kay studied in 1969 the terms denoting a color (excluding those which designate a shade by reference to a particular object). This study, called Basic Color Terms, took into consideration dozens of languages. They have thus found a hierarchy in these terms: when a language has only two terms, it distinguishes white from black; with three terms, it distinguishes white, black and colored, of which red is the most exemplary. When it has more than two terms, yellow, green, blue, brown, purple, pink, orange or gray are gradually added. "According to them, the colors of the sequence in question were always quoted in the same order, regardless of the region of the globe consulted. We always started with black and white, then came red, then green or yellow, yellow and green, blue and we ended with more nuanced colors such as brown, purple, pink, orange and gray."⁴

The red, appearing as the third "true" color, is placed in opposition to the two previous ones: "the white which means the undyed, and the black which means the dirty". Despite the particular meanings that these colors may acquire in different cultures, what interests us is the triad itself: white-black-red seems to be a

³ « The role of the pictogram can be decisive in situations that require rapid decision-making. This is the case for its use as instruction in the safety instructions in which it fulfills, according to Easterby and Hakiel (1981), three main functions: (i) to describe a situation with an image that makes it possible to identify the risk, (ii) prescribe an action with an image that indicates the action to be performed, and (iii) prohibit an action with an image that shows the prohibited action. We will add that it is also very useful to indicate the state of the situation in which one is and to allow the user to decide quickly, according to the conditions of the situation represented by the pictogram, the sequence of actions to implement » (translated from TIJUS. C et al,[16], p. 3.

⁴ Translated from Michel Albert-Vanel [17], p. 8.

basic triad whose values range from absence (white) to presence (black) through a third position that remains open (red).

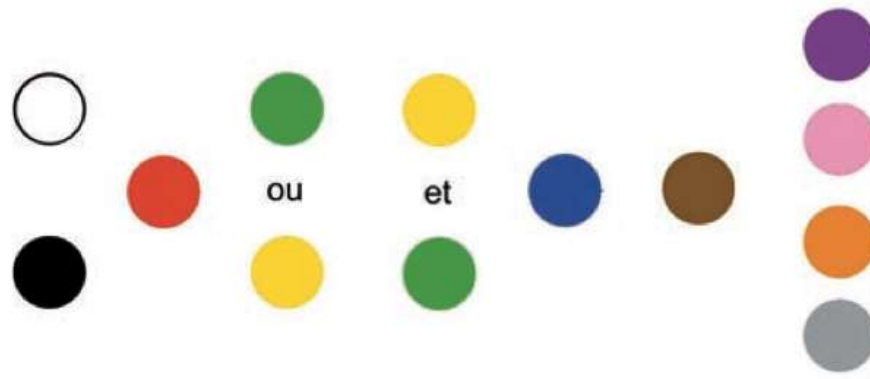


Figure 6: Berlin and Kay's sequence of colors

The primitive usage shows that the white/ocher-red/black triad has passed through the different ages of human history⁵. One example among others, the cave of Lascaux, located in the Périgord (France), one of the most important caves decorated with the Paleolithic, keeps parietal paintings and etchings whose age was estimated between about 18 000 and 17 000 years. Many fragments of dyes were discovered during the excavations in white, red and black materials⁶.

The white-black-red triad thus seems to be primitive. So it seems adequate enough to ensure a trans-cultural reading of the very simple symbolic values carried on:

- white = absent, empty;
- black = present, full;
- red = attain the relation absence / presence, empty / full

We can then construct a simple scale of values going from +/- absent to +/- present by changing from white to black on a red background.

We can so imagine a very simple system of pictograms based on these parameters:

- 4) red background = pay attention to this object because of the simple presence of the red color, that is to say the first color felt as color;
- 5) white inscription = absence of the objet / action represented;
- 6) black inscription = presence of the objet / action represented.

⁵ « Thus, in prehistoric paintings, we find, indeed, white, black, red, and the range extends to ochres, according to the different colors of the earth. Maybe, they used the green of the plants, but it was not preserved, and there was never any blue. [...] And after the civilizations of the earth, like those of Africa, it will be necessary to wait for more developed civilizations, like that of ancient Egypt, to see appearing other colors, in particular, the turquoise blue that the Egyptians and Persians were then alone to produce and use. » (translated from Michel Albert-Vanel, [17] p. 9.)

⁶ « The electron microscopic study of the dyes discovered during the excavations or taken directly on certain works showed their great diversity, at least seven different pigments having been used: manganese dioxide, black iron oxide and carbon (for black), hematite (for red), goethite and clay (for yellow), calcite (for white). All were used pure, without addition of mineral filler and without thermal modification. » Translated from https://fr.wikipedia.org/wiki/Grotte_de_Lascaux, article viewed on 10th November 2017.

According to this fundamental system based on the only relevant parameter absence / presence, how can we read, for example, these two pictograms?



Figure 7: The role of the colors triad in the interpretation of fire pictograms

According to the system designed,

- the first pictogram = white inscription on a red background = would mean: "attention! look at me ! there is no fire";
- the second pictogram = black inscription on a red background = would mean: "attention! look at me ! there is fire".

In such a case, the white inscription can thus be read as absence of danger, whereas the black inscription can mean as presence of the danger⁷.

Second and third goal: to show danger and induce behavior

Proprioception is the perception, conscious or non-conscious, of the position and movements of different parts of the body, thanks to numerous muscular and ligamentous receptors, and to the nervous pathways and centers involved.

The consciousness of the human body has always accompanied man: the ability to feel heat, pain, hunger, etc. are part of what is called "somesthesia", that is, the generalized ability to feel sensations from our organs, including "kinesthesia," that is to say perception of the position and movements of our organs, as a part of it. Proprioception concerns also the capacity of each individual to perceive their own body in order to be able to respond to their needs and dangers and thus guarantee their own survival.

This awareness of the body seems to be the only thing necessary to understand the two following categories of images having for object the human body, since each representation of the human body supposes to be aware of the position of the body with respect to itself and to the space around. This is valid:

- 1) from a phylogenetic point of view, that is to say, from the point of view of the human species, in rock art;

⁷ As Alain Navarro reminds us, the study of children's drawings shows that the use of colors is not trivial: "The presence of red, black and their associations, as well as some purple, for example, are the most well-known. In addition, current ethological research on primates studies other associations. Thus, red / white would trigger an aggressive panic (see road signs), while red / white / blue would be reassuring while maintaining the predatory vigilance (see the logos of supermarkets); red / blue would stimulate sexual aggressiveness and desire (see makeup), etc. "(translated from A. Navarro," The drawing of the boy in the child ", Document Circumscription Amiens 5. March 2003. Available on: <http://www.ac-amiens.fr/amiens5>)

- 2) from an ontogenetic point of view, that is to say from the point of view of the human individual, in the children's drawings.

Adopting these two points of view, we can assume that these kinds of representation are safe from cultural over-coding, because of

- from a phylogenetic point of view, we can speak about pre-historical individuals ;
- from an ontogenetic point of view, we can speak about the individual at the pre-school stage.

So, if we study closely these forms of representation of the human body, we can identify common elements that come back regularly:

- the presence of the head, normally of round shape;
- the presence of the limbs (upper and lower);
- the presence of a bust (more or less elongated).

These are the three essential elements to represent something that can be recognized as a human body.

To these elements, we can add those coming from the perception of the context [5]. These elements are reduced to three axes:

- a) up / down axis
- b) left / right axis
- c) axis of the depth.

An illustration of this is given by the following two pictograms:



Figure 8: The link of motivation: pictograms representing the human body in a context

These pictograms are currently used for signaling a risk of tripping and a risk of falling with unevenness. The interpretation of these signals is almost immediate since the user recognizes quite easily the dynamics of the body represented by the silhouette inscribed in the panel. The interpretation of these signals thus responds to a double ratio: first, a "ratio difficilis" by which we recognize in the silhouette a reference to the human body because of the isomorphism between the two plans of the sign (expression and content); then, a "ratio facilis" by which we recognize in the triangular form of the support an idea of danger by the internal reference to the other signs composing the system of signaling.

We can now compare these pictograms with these others whose interpretation depends exclusively on a "ratio facilis".



Figure 9: The link of convention: pictograms strongly based on cultural conventions

This is the case of the pictograms forming part of a system of signaling the danger concerning electricity and radioactivity that is recognized by reconstructing relationships with other associated pictograms. These pictograms then show that their production is based on a link of convention (relation between the signs belonging to the same system) which is stronger than the link of motivation (relation between the sign and the object and / or the experience). The pictograms produced by focusing on the convention link become immediately incomprehensible by ignoring the convention system they belong to.

Finally, to assure durability

After having explored several tracks such as the "nuclear priesthood" (T. Sebeok [18], nuclear hypothesis), hypothesis recently recalled (Sebastian Musch [19]) in order to invent rituals for transmitting information in behavior; artificial satellites constantly sending messages; the genetic manipulation of flowers becoming fluorescent next to a source of radioactive material ("atomic flowers", Stanisław Lem [20]), a principle of operation similar to that of "radiocats" (proposed by Françoise Bastide and Paolo Fabbri [21] [22] [23]); the installation of multilingual messages (Vilmos Voigt [24]); or an architectural trick that can protect a danger zone (Emil Kowalski), no researcher seems to have turned to the past by asking a simple question: what has been left to us from more than 10,000 years? One answer is very simple: stones⁸. And maybe it's the stones that should be returned.

The materials and techniques used do not change quickly in rock art. For about 25000 years, the walls of the caves housed representations characterized by an astonishing unity of techniques and themes. The silhouettes paintings of animals and humans are very common, as illustrated by Figure 10⁹.

⁸ Traces in terms of stones are the most general legacy of human beings from ancient past. However there exists also oral transmission over millennia, e.g among Australian aborigines. But the transmission track explored in this paper does not rely on continuous transmission from generation to generation.

⁹ Image from <http://www.lascaux.culture.fr/index.php?fichier=06.xml>



Figure 10: The various ages of rock art in France

The installation of stone "markers" for reporting the radioactive danger had already been proposed during the construction of the Onkalo storage site in Finland. It has been proposed in different forms: an obelisk incorporating both pictograms and texts; a kind of labyrinth-library whose walls had to learn to the visitors the nature of the danger, etc., as we can see by watching the documentary film "Into Eternity" (2010) which tells this experience.

The problems of interpretation concern mainly the following three aspects:

- 1) stone is not attractive in a natural environment, and we must find the way to make it attractive;
- 2) the type of inscriptions proposed are highly culturalized, so they aren't comprehensible in the long term;
- 3) for communication to be effective in such a case, the continuity of transmission must be guaranteed, which is exactly the opposite of the challenge.

If the inscription on the stone is the most resistant, we should find stones whose size and color can attract attention and recreate the triad of basic colors: white / red / black. It is for this reason that we can imagine the use of three stones in particular: the red hematite (whose color attracts attention in any natural environment known at present); the marble (extremely visible material on a dark background and extremely resistant, used since ancient times); the onyx (prestigious material whose lucidity allows a maximum of visibility).

CONCLUSIONS

The quest for trans-cultural and trans-generational performance requires that some universal semiotic features be identified, shared by human beings of various cultures nowadays, and from far in the past to the present.

The combination of "semiotic primitives », used as relevant semantic features of the object and/or the experience to be represented, and "toposensitive" criteria, used for pictogram production processes, would thus become a way to design a trans-cultural and transgenerational sign system for the signaling of radioactive danger.

The choice of the stone could guarantee the durability of the support; the color could guarantee its visibility; and both could guarantee the transmission of the message.

Combining these criteria could open the way to a communication system about radioactive waste repositories.

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