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# AN EMPIRICAL INVESTIGATION OF LEXICAL AND COGNITIVE NETWORKS IN THE BRAIN

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## 1. INTRODUCTION

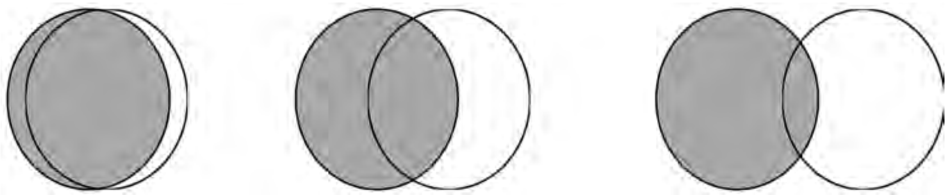
A topic scholars have been interested in for many years is the relationship between language and cognition. Does language determine the structure of the human mind, so every natural language reveals a specific way of interpreting reality? Or, on the contrary, does cognition remain relatively independent from natural language? A century after the Sapir-Whorf hypothesis was formulated, there is no conclusive proof supporting either point of view.

The problem is: what form should such proofs take? Certainly, meanings differ from one language to another. But this does not prevent the existence of a common cognitive ground underlying all these meanings. Pinker (1995) called it *mentalese* and defined it in the glossary of his book as follows: "The hypothetical language of thought, or representation of concepts and propositions in the brain, in which ideas, including the meanings of words and sentences, are couched." Without mentioning Pinker's other assumptions, like the innate origin of mentalese, which could be tracked back to our genes (!), a problem arises when looking for empirical facts to back such theses. The reason is that, neurologically speaking, we cannot isolate the linguistic meanings from the cognitive meanings that underlie them. As pointed out by Lamb (1998: 372-374):

> "And so if we ask what is innate (for some reason a popular question nowadays), maybe the answer is that the most distinctive innate features of our cortices, those which make us most different from other mammals, are the increased abundance of cortical columns and of their interconnections, including the fantastic possibilities of interconnection made possible by the long-distance axon bundles, and the really wonderful fact that only

> a small minority of them are innately hard-wired … The mind is not a device for storing and rewriting symbols but a network system, whose information is in its connectivity"

In other words, the neural networks of the human brain that support our cognition of an object are basically the same networks that support its corresponding linguistic concept. Cognitions and meanings do not belong to separate stores in the mind. However, they are not equivalent to each other since an object like the fruit that God prohibited Adam and Eve in paradise is called *apple* in English, *manzana* in Spanish, *pomme* in French, *ringo* in Japanese, and so on. From a naive point of view, these names are considered to be tags we can substitute freely, but linguists know they are not, as every noun has its own specific set of referents it can apply. We can conclude that cognitions and meanings should overlap to some extent:



A: high B: medium C: low

[The grey circle corresponds to cognition and the white one to meaning]

Correlations can be high (A), medium (B), or low (C). Moreover, we could expect that the degree of correlation does not characterize the entire lexicon of a given language in the same way. There should be some semantic fields whose cognitions strongly depend on the words that symbolize them, whereas in other semantic fields words and cognitions are rather loosely tied together. For example, scientific or technological vocabulary probably belongs to the first field, ordinary life terms to the second. Thus, people cannot figure out the meanings of "polygon" without referring to the pictures and definitions they learned at school, but they have their own inventory of aches no matter what names the language uses to designate them.

## 2. Methodology

This research attempted to investigate the correlations between a list of ten linguistic items, provided to the participants in this study, and their corresponding cognitions, which were called forth by visual images. A randomization technique was exploited to select one hundred participants, from among university students in Valencia, Spain. Then, they were randomly divided into control and experimental groups. Participants are Spanish speakers, although most of them are bilinguals, who also speak Catalan.

The items they were given belong to two semantic fields, COLORS and MEANS OF TRANSPORT, which were presented to participants as an unordered set of words, and as an unordered set of visual images:

| **COLORS** | **MEANS OF TRANSPORT** |
|---|---|
| Negro (black) | Coche (car) |
| Azul (blue) | Moto (motorbike) |
| Rojo (red) | Bicicleta (bicycle) |
| Naranja (orange) | Patín (skates) |
| Verde (green) | Camión (truck) |
| Amarillo (yellow) | Avión (plane) |
| Rosa (pink) | Barco (boat) |
| Morado (purple) | Tren (train) |
| Marrón (brown) | Autobús (bus) |
| Blanco (white) | Tranvía (tramway) |

These two semantic fields were chosen in order to oppose a set of cognitions that can be labeled as *natural* to another set of cognitions, which depend on cultural determinations, and that could be considered more *artificial*. Of course, the opposition nature vs. nurture only holds for visual images, not for words. As it is well known, the set and chromatic distribution of the colors people are able to distinguish are highly dependent on the corresponding words in their native language (Berlin and Kay 1969; Saunders 2000). However, to some extent colors are perceived independently of the words that refer to them because this process is strictly biological and it is ultimately supported by the wave lengths of the perceived light spectrum. On the contrary, the means of transport that are commonly used in a given culture rely on the existing artifacts, with each being characterized by a specific word. Consequently, two main assumptions can be made on this topic:

1) Words and visual images (pictures) referring to means of transport are presumably sustained by the same neural networks in the brain, therefore they should hold a one to one relationship;
2) Words and visual images (colored cards) referring to colors are sustained by partially non coincident neural networks in the brain, therefore they should hold a manifold relationship.

## 3. STATISTICAL TOOLS

Our experimental data have been examined by means of two statistical tests: Goodmann and Kruskal's gamma (G) and p-value. The former is a measure of rank correlation, i.e., the degree of similarity in orderings of the data when ranked according to quantities. G measures the strength of association of the cross tabulated data when both variables are measured at the ordinal level. Values range from −1 (perfect inversion) to +1 (perfect agreement), the absence of association being signaled by zero. As pointed out by Masson and Rotello (2009) in many cognitive, metacognitive and perceptual tasks, G measures are very helpful.

Proof conducted by G measures can be customized by p-value, representing the cut-off value at which a test is considered statistically significant. The p value is the likelihood that the results of a statistical test are due to random error. In social sciences, cognitive linguistics among them, significance is assumed when $p < 0.05$. In statistics, the concept of null hypothesis means that there is no relationship between two measured phenomena; therefore, in the experiment we are describing, the null hypothesis would mean that no relationship at all can be established between the ordinal positions of the words and the ordinal positions of the images. Then, the null hypothesis is rejected when the p-value is less than 0.05. In our experiment, the observed result would be highly unlikely under the null hypothesis and, consequently, associations cannot be due to random chance.

## 4. Results

The following results were obtained:

*Colors*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Γ | 0.4970 | 0.3713 | 0.3979 | 0.3925 | 0.5241 | 0.3346 | 0.3640 | 0.2998 | 0.3020 | 0.5402 |
| p-value | 0.019 | 0.078 | 0.052 | 0.048 | 0.019 | 0.080 | 0.072 | 0.107 | 0.119 | 0.018 |
| rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Means of transport*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Γ | 0.4758 | 0.3523 | 0.5867 | 0.4645 | 0.4218 | 0.5817 | 0.4756 | 0.3898 | 0.2156 | 0.3450 |
| p-value | 0.019 | 0.086 | 0.009 | 0.031 | 0.049 | 0.007 | 0.026 | 0.050 | 0.204 | 0.078 |
| rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Goodman & Kruskal's gamma*

We are comparing predicted rankings versus actual rankings. Positive coefficients indicate more concordant than discordant pairs, whereas negative coefficients indicate the contrary. Since Goodman and Kruskal's gamma is approximately normally distributed for large samples, it is possible to calculate p-values and a level of significance. As it can be seen, G-values are always positive, therefore the null hypothesis does not hold. Both colors and means of transport show concordances between a given word and its corresponding image, thus the neural networks that support them should partially overlap. The degree of concordance falls between 0.2156 and 0.5867 in the transport list and between 0.2998 and 0.5402 in the colors list. The gap is broader in the former, probably because colors are natural values that result from decomposition of the white light forming an integrated spectrum. However the average concordance degree in the transport list is 0.4408, whereas the average concordance degree in the colors list is 0.4023. This can be interpreted in the sense that culture imposes a tight overlapping of neural networks in the case of the means of transport because they are acquired as cognition together with the corresponding word, which does not hold for colors.

*P-values*

The p-values for the color list show weak evidence against the null hypothesis: 70% are over the cut off value of 0.05. This can be interpreted in the sense that color words and color visual images do not correlate in the brain, each of them being supported by their own neural networks, even though reciprocal connections certainly exist.

The p-values for the transport list show moderate evidence against the null hypothesis: 60% are under the cut-off value of 0.05. Some p-values even show strong evidence against the null hypothesis for they fall between 0.01 and 0.05. This can be interpreted in favor of the alternative hypothesis in the sense that the words referring to means of transport and the perceptual images relating to them are supported by strongly correlated neural networks.

## 5. CONCLUSIONS AND FURTHER RESEARCH

The results of this investigation show that the Sapir-Whorf hypothesis neither holds absolutely, nor fails absolutely, but depends upon the nature of the referent. It seems that the lists of words belonging to cultural domains correlate with the lists of the corresponding images that represent them, whereas in the case of the lists of words that refer to natural phenomena this correspondence is much weaker. Notwithstanding, further research should be made in greater depth by considering other semantic fields of both types, and by enlarging sample size. It would be also advisable to extend the research to include more languages in two ways: i) to collect data from other languages, and ii) to collect data in the mother tongue and in a second language at the same time.

## NOTE

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