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Visual content of words delays negation

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ABSTRACT

Many studies have shown the advantage of processing visualizable words over non-visualizables due to the associated image code. The present paper reports the case of negation in which imagery could slow down processing. Negation reverses the truth value of a proposition from false to true or vice versa. Consequently, negation works only on propositions (reversing their truth value) and cannot apply directly to other forms of knowledge representation such as images (although they can be veridical or not). This leads to a paradoxical hypothesis: despite the advantage of visualizable words for general processing, the negation of clauses containing words related to the representation of an image would be more difficult than negation containing non-visualizable words. Two experiments support this hypothesis by showing that sentences with a previously negated visualizable word took longer to be read than sentences with previously negated non-visualizable words. The results suggest that a verbal code is used to process negation.

1. Introduction

Negation is essential in language comprehension since it is present in all natural and artificial languages and is used by children from an early age. Its functional in sentential logic is to take a proposition and reverse its truth value (reverting false to true and vice versa). In other words, if the proposition *P* is false (e.g., Pope Francis is a Marxist), then *Not P* is true (e.g., Pope Francis is not a Marxist) and vice versa (Aristotle, 1984). *Propositions* are the smallest units of knowledge that can be true or false. Consequently, the traditional view is that negation works only on propositions (reversing their truth value) and cannot apply directly to other forms of knowledge representations such as images that are not in principle true or false arguments. From this point of view, negation cannot have a perceptual representation.

However, some authors have defended recently an alternative account where negation does apply directly to images (Oversteegen & Schilperoord, 2014; see also Waskan, 2006). They presented images and observed that participants described them with a negation. Negation could be one interpretation among others. For example, the image of a face without a mouth could be interpreted as 'the woman does not have a mouth', or 'silent', or 'be quiet in the room' or 'rights for women'. Nevertheless, all these interpretations do not tell us what negation means, but what the image means, and images have many interpretations. Following Wittgenstein (1953), Johnson-Laird (2006) pointed out that we could superimpose an image of a large red cross on the image of a cabinet behind the piano to represent: 'the cabinet is not behind the piano', or we also could represent the cabinet in front of the piano, to the left of the piano, to the right of the piano, below the piano, and so on. Nevertheless, we would have to know that a cabinet in front of the piano or a large cross on the image of a cabinet behind the piano means, 'the cabinet is not behind the piano' because nothing in the image captures the meaning of negation: if a proposition is true then its negation is false, and vice versa. Of course, an image can be veridical or not with respect to reality or to a sentence, but there is no way to draw an image signifying that 'the cabinet is not behind the piano'. We can draw images that are compatible with this sentence, but the negation included cannot be captured without symbolic operation.

Concepts differ in imageability, and the ease with which we can represent a concept with an image will affect how we process it. Concrete concepts are processed more quickly and accurately than abstract concepts in a variety of tasks, such as word recognition, lexical decision, recall, problem-solving, and reasoning (for a review of the classical concreteness effect, see Denis, 1989). Indeed, this effect has been related to an image code that could be implicated in the processing of concrete concepts but not of abstract concepts. This dual coding theory (Paivio, 1991, 2013) has found support in recent neuroimaging studies showing that neural representations of concrete concepts, while involving both an image code and a verbal code, tend to rely more heavily on the former, while the representation of abstract concepts relies more heavily on the latter (see Wang, Conder, Blitzer, & Shinkareva, 2010 for a meta-analysis). The advantage of concrete concepts over abstract concepts could be related to the greater processing demands needed

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to construct images (cf. Johnson-Laird & Bethell-Fox, 1978). This type of representation is more structured and elaborated than verbal representation, and consequently leads to a richer and deeper semantic processing (cf. Craik & Tulving, 1975).

We decided to use visualizable and non-visualizable words instead of concrete or abstract concepts. The main reason underlying this choice was that it is unclear exactly what information is captured by concreteness. For example, imageability and concreteness, though technically different psycholinguistic constructs, are closely related: imageability ratings explain more than 72% of the variance in concreteness ratings (Reilly & Kean, 2007). In Paivio (2013), concreteness is defined in terms of the directness of the sensory reference that can be determined using a dictionary, while imageability is defined as a psychological attribute that can be inferred only from psychological measures. Also, concreteness can refer to five different modalities: visual, auditory, haptic, gustatory and olfactory. Connell and Lynott (2012) demonstrated the relationship between concreteness, imageability and each of these modalities. They also studied how these variables affect lexical decision and naming tasks. The conclusion was that perceptual strength ratings are the better predictor, and so concreteness effects could be best characterized as perceptibility effects. In sum, it would be advisable, for our purposes, to base our study on visualizable words instead of on concreteness because the former is a specific variable, and we therefore have more control over it.

Taken together, this means that visualizable words will be easier to process, as they are represented using image codes; however, negation applies only to propositions (or verbal codes), not to images. This yields a paradoxical situation: visualizable words should be easier to process than words that are not visualizable, whereas negation should reverse the effect. Negation applies only to the verbal code, and so the activation of the image code in the case of visualizable words is irrelevant and may even impede processing.

To test this hypothesis, we carried out two experiments using a subtle methodology. In Experiment 1, there were two conditions depending on whether the negation was applied to a visualizable or non-visualizable word. Each trial had two sentences. Each sentence contained two adjectives, one referring to a property that would be easy to visualize (the visualizable word; e.g., asleep) and the other referring to a property that was hard to visualize (the non-visualizable word; e.g., brave). In the first sentence, one of these two words was negated (i.e., for the visualizable condition: *The boy was brave and he was not asleep*). This negated word was replaced with an antonym in the second sentence (i.e., *The boy was brave and he was awake*). This methodology allows us to have the same target (the second sentence) for visualizable and non-visualizable conditions. An example for the non-visualizable condition would be as follows: *The boy was awake and he was not cowardly*. *The boy was awake and he was brave*. Readers should note that the second sentences of both conditions are similar, thus avoiding possible lexical and sub-lexical effects, among others (the same words were used throughout the experiment for each condition). To date, this control has not been introduced in other paradigms that employed different targets and allows us to control lexical and sub-lexical effects. For example, Tettamanti et al. (2008) used *Now I push the button* as an action condition and *Now I appreciate the loyalty* as an abstract condition.

The dependent variable of Experiment 1 was the time that participants took to read the second sentence. The predicted result is that participants should take longer to read the second affirmative sentence (the target sentence) after a sentence containing a clause with a negated visualizable word than after a sentence containing a clause with a negated non-visualizable word. It should be harder to understand the negation of a visualizable word than the negation of a non-visualizable word, and as a consequence, it should be harder to understand its equivalent affirmative in the second sentence. We measured the second sentence instead of the first because the second sentence is similar for both conditions, and we wanted to be sure that the effects are due to the kind of words negated (visualizable or not), and not to other properties of different words.

In Experiment 1, the first sentence had a negative clause (e.g., *The boy was not asleep*) and the second sentence expressed the same proposition in an affirmative clause (e.g., *The boy was awake*). Many studies have shown that in binary negation (see Wason, 1961), predicates such as "asleep" and "awake" in which the negation of one implies the affirmation of the other, participants tend to transform a negation, such as "not asleep" into "awake" (see also Kaup, Lüdtke, & Zwaan, 2006). Therefore, it is arguable that our results are a consequence of the representation of the affirmative alternative rather than the negation. To rule out this possibility, we designed Experiment 2, in which the negative concepts were preserved in the target sentences. Here, we used sets of three sentences, such as:

John said that the boy was brave and he was not awake.
John was wrong.
The boy was brave and he was awake.

With this change, the third sentence (the target) used the same words as the first one (brave and awake). On half the trials, the third assertion was inconsistent with John´s assertion (see example above) and in the other half it was consistent with his assertion, such as:

John said that the boy was brave and he was not asleep.
John was right.
The boy was brave and he was awake.

Both clauses in the third assertion were always affirmative. The predicted result was that participants should be faster to read the third sentence when the first sentence contains a negated non-visualizable word than when it contains a negated visualizable word, as in Experiment 1.

2. Experiment 1

The aim of Experiment 1 was to test whether the negation of clauses containing visualizable words would be slower than the negation of clauses containing non-visualizable words when we presented the alternative affirmation.

2.1. Method

2.1.1. Participants

Eighty-two native Spanish speakers from the University of La Laguna, Tenerife (Spain), participated in the experiment in exchange for course credits.

2.1.2. Materials and procedure

Two normative studies were carried out before the experimental study.

2.1.2.1. The first normative study. The goal of the first normative study was to select the material, which consisted of visualizable and non-visualizable words with clear antonyms. We presented 80 sentences (20 pairs of visualizable and non-visualizable words and their antonyms ($20 \times 4 = 80$)). Seventy-six students of the University of La Laguna (64 females; mean age: 22 years), different to those forming the experimental sample, had to write the antonym of each word and estimate the degree of visualization in the choice using a Likert scale from 1 to 5. For example, *The boy was asleep*. *The boy was…* The underlined words were obtained from the Spanish free-association norms (Fernández, Díez, Alonso, & Beato, 2004). All the experiments were carried out in Spanish (including all the materials and instructions and the crucial words), which, for the convenience of readers, we have translated here into English. The selection criterion for visualizable and non-visualizable words was that they must have a clear antonym, i.e., the percentage of agreement about the antonym must be above