



## How negation is understood: Evidence from the visual world paradigm



Isabel Orenes\*, David Beltrán, Carlos Santamaría

Universidad de La Laguna, Tenerife, Spain

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### ABSTRACT

This paper explores how negation (e.g., *the figure is not red*) is understood using the visual world paradigm. Our hypothesis is that people will switch to the alternative affirmative (e.g., a green figure) whenever possible, but will be able to maintain the negated argument (e.g., a non-red figure) when needed. To test this, we presented either a specific verbal context (binary: *the figure could be red or green*) or an unspecified verbal context (multary: *the figure could be red or green or yellow or blue*). Then, affirmative and negative sentences (e.g., *the figure is (not) red*) were heard while four figures were shown on the screen and eye movements were monitored. We found that people shifted their visual attention toward the alternative in the binary context, but focused on the negated argument in the multary context. Our findings corroborated our hypothesis and shed light on two issues that are currently under debate about how negation is represented and processed. Regarding representation, our results support the ideas that (1) the negative operator plays a role in the mental representation, and consequently a symbolic representation of negation is possible, and (2) it is not necessary to use a two-step process to represent and understand negation.

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### Introduction

Negation is an important element of language with considerable cognitive consequences. It changes the truth value of assertions (reverting true to false and vice versa), and, interestingly, it does so by representing the world in a way that deviates from what is simply the case. An affirmative sentence like “the car is red” refers to the world in a direct way, in that it describes an entity (a car) that has the property of being colored red. Yet, the simple addition of the word “not” to the same sentence (e.g., “the car is not red”) comes to refer to something profoundly different: a world in which it is not the case that the property of being

colored red applies to the entity referred to in the sentence. In the present study, we make use of the visual world paradigm to explore how people comprehend and represent the world from negations. In particular, we focus on the two issues that are currently the subject of much debate in negation comprehension: (1) what role in negation comprehension, if any, does the negative operator play in the mental representation encoded by hearers, and (2) how many representational steps are triggered, and necessary, to understand a negative?

#### Theories about negation comprehension

Cognitive accounts of negation can be analyzed in terms of two domains of divergence. First, they diverge with respect to the role given to the negation operator in the mental representation that becomes encoded during comprehension. One view is that the negative operator forms part of the mental representation of the world, as a ‘mental

\* Corresponding author. Address: Universidad de La Laguna, Departamento de Psicología Cognitiva, Campus Guajara, sn 38205 La Laguna, Tenerife, Spain.

E-mail addresses: [iorenes@ull.es](mailto:iorenes@ull.es) (I. Orenes), [dbeltran@ull.es](mailto:dbeltran@ull.es) (D. Beltrán), [csantam@ull.es](mailto:csantam@ull.es) (C. Santamaría).

tag' (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso, Rollins, & Shaughnessy, 1971). For others, in contrast, it is simply an element of discourse, which has no explicit representational correspondence in the mind (Barsalou, 1999, 2005, 2008, 2012; Glenberg, Meyer, & Lindem, 1987; Zwaan & Radvansky, 1998). The second source of disagreement between scholars concerns the processing dynamic that underlies negation comprehension. For some, two mental representations are always sequentially encoded during negative sentence comprehension, such that the processing of negation becomes characterized in the shift from one representation to another (Kaup, Lüdtke, & Zwaan, 2006). For example, shortly after reading a sentence like *'The door is not open'*, one would first encode a representation of an open door and then later encode a different, alternative representation (e.g., a closed door). For others, however, this shift between two mental representations is not obligatory, because either the mental representation of the negated content is enough to support the comprehension process (e.g., Clark & Chase, 1972) or because the representation of the alternative state of affairs occurs automatically, without having to represent the negated argument (Anderson, Huette, Matlock, & Spivey, 2010; Tian, Breheny, & Ferguson, 2010).

At least three representational accounts can be distinguished according to the above classification. First is the classical, propositional theory of negation, which holds both that negation is directly, mentally represented and that there are two ways of processing negative sentences during comprehension. One of these ways would involve the representation of the negated argument together with the negative operator (e.g., NOT[DOOR OPEN]), which is considered to suffice for comprehension (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso et al., 1971). The other way would involve the recoding of the negated argument into an alternative affirmative (e.g., NOT[DOOR OPEN] into AFF[DOOR CLOSED]). This theory does not currently enjoy much support among researchers, likely due to its overreliance on propositional representations. However, it is worth remarking that the two ways of processing negation that it proposes fit nicely with much of the extant evidence about negation processing (for a review, see Kaup et al., 2006).

On the opposite side of the propositional theory, we have the recently proposed two-step simulation theory, which is framed in the more general embodiment view. This theory rejects the idea that negation operators can figure in one's mental representation of a sentence. Instead, it suggests that negation comprehension depends on a process that uses solely mental representations that are completely grounded in sensorimotor experience. This process always begins with the simulation of the negated argument (e.g., an open door) and continues with the simulation of the alternative (e.g., a closed door). This theory holds that these two steps are mandatory for comprehension, even when the alternative is not available. In those cases, comprehenders might represent the negated argument that they will later reject to represent the alternative affirmative, although this simulation could be empty (Barsalou, 1999) or unspecified. For example, *the door is not blue* could well be simulated by representing a door

of an unspecified color (Kaup, Zwaan, & Lüdtke, 2007). Within the framework of perceptual-simulation theories, it has been also proposed (Anderson et al., 2010) that rather than a two-step sequence of static images, negation would be represented by the derivative over time in a perceptual simulation.

Finally, somewhere in the middle between perceptual-simulation and propositional theories we find the Mental Model theory, or model theory for short (Johnson-Laird, 1983, 2006). This theory holds that many of the mental representations used during comprehension and reasoning are simulations (mental models) that do not directly represent the linguistic input. Nonetheless, it does not exclude the possibility that the human cognitive system can encode iconic and symbolic representations during comprehension. According to the model theory, individuals understand negation by simulating either the alternative affirmative or the negated argument while applying a symbol that represents negation (Khemlani, Orenes, & Johnson-Laird, 2012). Consider the following assertion: *the circle is not to the right of the triangle*. In order to understand this situation, model theory predicts that individuals will construct an iconic model of the corresponding affirmative assertion and then apply the negation symbol. The resulting model might look like this:



The symbol of negation ( $\neg$ ) does not mean that people represent negation like that. It is unknown how people represent negation. They may represent the iconic model with a superimposed cross or represent negation via a marker of falsity, as Clark and Chase (1972) proposed. What is clear is that the operator of negation can only be represented symbolically, thus individuals have to know that the symbol stands for negation, because nothing in the image could tell them that (Wittgenstein, 1953).

In sum, all theories agree that negation takes an argument and rejects it. The difference between the theories would be in the necessity of representing the alternative affirmative. If people represent the alternative to understand negation, the resulting representation is iconic, because negation is not represented explicitly, thus this finding supports the embodiment theory. However, if they represent just the negated argument, this representation should be symbolic, or at least not purely iconic, because a symbolic marker is needed to represent negation without swapping to the alternative. This latter finding would suggest that individuals are able to represent symbolic information.

### The present study

The goal of the present study was to determine whether accessing the alternative affirmative is necessary to understand negation, or just one possibility. Our hypothesis is that the way in which individuals understand negation is modulated by the availability of the alternative affirmative. In other words, people could represent the alternative when it is available, such as in binary (or complementary) predicates: in the case of 'not odd', there is only one

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