Spatial representation of linguistic quantifiers: small goes left, big goes right

Quantifiers can be defined as linguistic expressions that convey information about quantity of sets of objects. They are complex in many respects: they cannot be reduced to simple measure phrases referring to amounts; at the same time, they are not simple referential expressions, since they do not directly denote objects or entities. From a semantic standpoint, there are several classifications of quantifiers based on different dimensions. For instance, we can distinguish between Definite and Indefinite quantifiers based on the definiteness of the set denoted, or High-magnitude and Low-magnitude quantifiers, when considering the size of the set.

How these words are represented in the human mind has been a topic of great debate in the last years (Troiani et al., 2009; Heim et al., 2012; Shikhare et al., 2015). The mental representation of quantifiers has been described in terms of distributions over scales (Moxey & Sanford, 1993; Pezzelle et al., 2018). The most debated issue is whether non-numerical and non-proportional quantifier processing is related to number cognition or whether it exclusively relies on linguistic processes.

Robust effects that are found in numerical cognition are the (i) “Distance effect” and the (ii) “Size effect” (Moyer & Landauer, 1967): respectively (i) the larger the distance between two numbers to be compared, the better the performance (i.e. lower response times); and (ii) the comparison of two numbers is easier for small than for large numbers. Furthermore, it is a well attested fact that numbers are represented along a “mental number line”, according to which small numbers are spatially represented on the left and large numbers are spatially represented on the right (Dehaene, Bossini, & Giraux, 1993).

Our study. The present study aims at exploring how indefinite (non-numerical) quantifiers are represented in spatial terms in the human mind. We adapted an experimental paradigm used in the field of number cognition in order to investigate whether there are similarities between quantifier and number-word processing. We tested 50 Italian native speakers. Participants performed two different experiments, one involving only number words and the other exclusively involving quantifiers. Two words were presented simultaneously on a computer screen and participants had to choose the word expressing the larger/smaller amount.

We tested 10 number words and 10 quantifiers. Numbers ranged from “zero” to “four” (Low-Magnitude numbers) and from “five” to “nine” (High-Magnitude numbers). Five of the quantifiers were classified as Low-Magnitude (nessuno, “nobody”; niente, “nothing”; pochi, “few”; alcuni, “some”; qualche, “some”) and 5 as High-Magnitude (tutti, “all”; ogni, “each/every”; molti, “many”; tanti, “many”; parecchi, “several”). Stimuli appeared in two conditions (randomly presented and counterbalanced): a *congruent condition* in which Low-Magnitude items appeared on the left and High-Magnitude items appeared on the right; and an *incongruent condition* in which the spatial positioning was reversed (Figure 1).

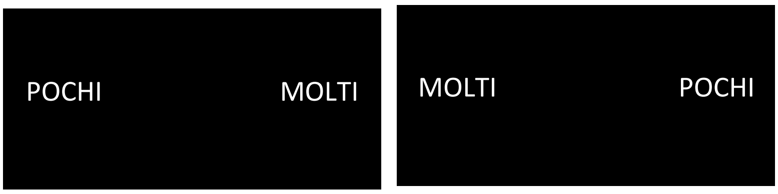
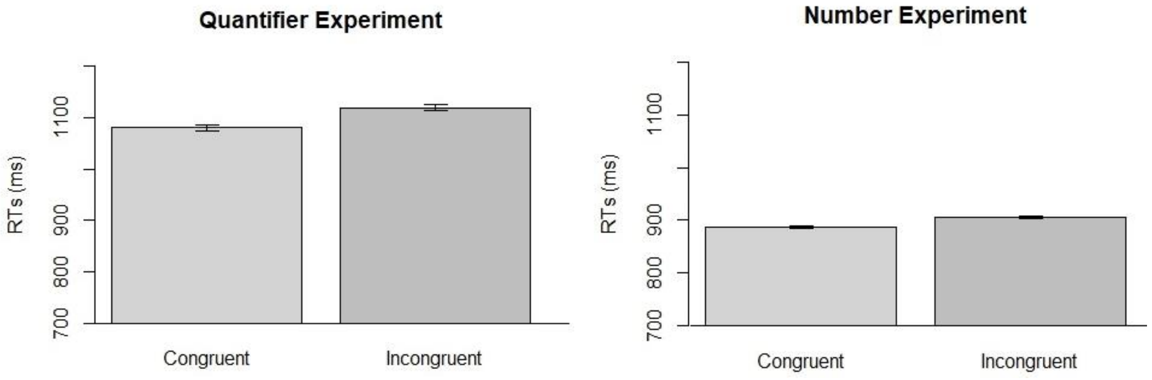


Figure 1. Example of the congruent (left panel) and incongruent (right panel) conditions.

Results. Data were analyzed using linear mixed-effects model with response times as dependent variable, condition as independent variable and items and subjects as random intercepts. In both experiments, RTs resulted to be significantly faster in the congruent than in the incongruent condition ($t(3.75)=6.064$, $p<.0001$ for quantifiers and $t(6.09)=12.41$, $p<.0001$ for numbers).

Figure 2. RTs in congruent and incongruent conditions in the Quantifier Experiment and in the Number Experiment.



In line with previous literature (Dardano and Trifone, 1997; Zamparelli, 2008), we next assigned a numerical value (from 0 to 6) to each of the quantifiers, to represent the “size” of each quantifier and correlate it to the RTs. Quantifiers resulted to be sensible to the effects that are typically seen in number cognition, such as the “Distance effect” and the “Size effect”: the greater the distance between two quantifiers, the less participants take to respond ($r= -0.224$, $p<.0001$); the smaller the “size” of the quantifier, the faster the response ($r= 0.129$, $p<.0001$). We fully replicated the same (expected) pattern for numbers($r=-0.203$, $p<.0001$ for the “Distance effect”, $r=0.088$, $p<.0001$ for the “Size effect”)

Discussion. Our findings suggest that, in the human mind, quantifiers are represented on an ordered spatial mental continuum, in which elements denoting smaller sets are placed at the beginning of the scale, namely on the left, and those denoting larger sets are represented on the right. This representation reflects what is well-known as the “mental number line”, according to which small numbers are spatially represented on the left and high numbers are spatially represented on the right (Dehaene, Bossini, & Giraux, 1993). Moreover, we found that quantifiers manifest two typical experimental effects found in number cognition, namely the “Distance effect” and the “Size effect”. This suggests that quantifiers are processed as analog magnitudes, at least in a task like the present one. These results might serve as a starting point for further investigation of the interplay between language processes and spatial-numerical representations in human cognition (see, e.g., Rinaldi & Marelli, 2020).

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