# Cognitive processing of verbal quantifiers in the context of affirmative and negative sentences: A Croatian study

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**Abstract**
Studies from English and German have found differences in the processing of affirmative and negative sentences. However, little attention has been given to quantifiers that form negations. A picture-sentence verification task was used to investigate the processing of different types of quantifiers in Croatian: universal quantifiers in affirmative sentences (e.g. all), non-universal quantifiers in compositional negations (e.g. not all), null quantifiers in negative concord (e.g. none) and relative disproportionate quantifiers in both affirmative and negative sentences (e.g. some). The results showed that non-universal and null quantifiers, as well as negations were processed significantly slower compared to affirmative sentences, which is in line with previous findings supporting the two-step model. The results also confirmed that more complex tasks require a longer reaction time. A significant difference in the processing of same-polarity sentences with first-order quantifiers was observed: sentences with null quantifiers were processed faster and more accurately than sentences with disproportional and non-universal quantifiers. A difference in reaction time was also found in affirmatives with different quantifiers: sentences with universal quantifiers were processed significantly faster and more accurately compared to sentences with relative disproportionate quantifiers. These findings indicate that the processing of quantifiers follows after the processing of affirmative information. In the context of the two-step model, the processing of quantifiers occurs in the second step, along with negations.

**Keywords**: verbal quantifiers, negation processing, two-step model

## 1. Introduction

A vast body of research from English and German has shown that affirmative sentences are processed significantly faster compared to negative sentences (Cheng and Huang, 1980; Clark and Chase, 1972; Just and Carpenter, 1971; Kaup, Lüdtke and Zwaan, 2005; Margolin and Abrams, 2009). This implies that the processing of negations is more complex than the processing of affirmatives. According to the Situational Model of sentence comprehension (Van Dijk and

Kintsch 1983; Zwaan 1999; Zwaan and Madden 2004, 2005; Zwaan and Radwansky, 1998), sentence processing elicits a mental model, based on a situation described in the sentence. The two-step model of negation processing (Kaup, Lüdtke and Zwaan 2005, 2006) assumes that negations are processed in two stages: first, they are processed as affirmatives, with negation being added in the second step. This results in longer reaction times and lower accuracy of answers in behavioral studies of negation processing. Kaup et al. (2006) offer the following example: "The door was not open". In the first step the door is mentally processed as open. In the second step, the situational model that was created is negated. The final result is "not open door" or semantically, the closed door.

In research on negation processing, little attention has been given to the role of verbal quantifiers. In some negations, negative markers are quantifiers (e.g. "Nobody came to the party"). In psychology, quantifiers are mostly investigated in the context of psychological inventories and scales (Burusic 1999; Newstad, Pollard and Riezebos 1987), acquisition of quantification (Gennari and MacDonald 2006; Hurewitz, Papafragou, Gleitman and Gelman 2006), deductive reasoning (Geurts 2003; Johnson-Laird 1999) and proportion amount processing (Geurts, Katsos, Cummins, Moons and Noordman 2010; Merin 2005). However, they have not been thoroughly investigated in the context of negation processing.

The importance of quantifiers can be seen in Slavic languages, where negations are often formed by quantifiers as negative markers. Croatian, for example, allows double negations and negative concord, unlike English or German (Baric, Hudecek, Koharovic, Loncaric, Lukenda, Mamic, Mihaljevic, Saric, Svacko, Vukojevic, Zecevic, and Zagar 1999; Kordic 2004; Menac 1953; Zovko Dinkovic 2013). Double negation refers to a sentence with two negations and a semantically positive meaning (e.g. "The ball isn't uncolored."). Negative concord, on the other hand, refers to a semantically negative sentence with two negations (Van der Wouden and Zwarts 1993). English allows double negations, but negative concord is considered grammatically incorrect (Coles-White 2004; Kallel 2011; Van der Wouden and Zwarts 1993). Sentences with negative concord (e.g. "He doesn't like *no* sports.") can be found in non-standard English, and are usually associated with lower social status and lower education of the speaker (Eckert 2004; Wolfram 2004). In Croatian, negative concord is mostly formed by negation of universal quantifiers. If a universal quantifier, e.g. "*Svi avioni su sletjeli"* (Eng. "All planes landed"), is negated to make a non-universal quantifier, as in "*Nisu svi avioni sletjeli*" (Eng. Not all planes landed), it still remains a one-negation sentence. But if a universal quantifier is negated with a null quantifier, e.g. "*Nijedan avion nije sletio*" (Eng. None of the planes did *not* land), the verb must be matched with the polarity of the null quantifier. Moreover, if the sentence contains a null quantifier, all undefined parts of the sentence must match their negative form (Zovko Dinkovic 2013). For example, negation of quantifiers like *svi* (Eng. *all*) into *nijedan* (Eng. *none*), e.g. "*Nijedan*

*avion nije sletio*" (Eng. None of the planes did *not* land), forms negative concord with negated verb and a null quantifier, resulting in a negative meaning. Moreover, affirmative sentences with relative disproportional quantifiers, such as "*Neki avioni su sletjeli"* (Eng. "Some planes land"), can also be negated in two ways. The verb can be negated with a relative disproportional quantifier, e.g. "*Neki avioni nisu sletjeli"* (Eng. "Some planes didn't land"). A quantifier, on the other hand, can be negated as a sentence with a non-universal quantifier "*Nije svaki avion sletio"* (Eng. "Not every plane landed"), or as a sentence with a null quantifier "*Nijedan avion nije sletio*" (Eng. None of the planes did *not* land). This example illustrates that, in the case of negative concord, null quantifiers can act both as negations of universal quantifiers as well as negations of affirmative sentences with relative disproportionate quantifiers.

In linguistics, quantifiers are defined as words that express quantity. They can differ in their extension and polarity (Zovko Dinkovic 2013). The extension is clear in sentences with universal quantifiers such as *all*, *every* or *always,* where quantifiers imply an entire set (e.g. "All boxes are red"). Negation of universal quantifiers forms negative (null) quantifiers like *none*, *no* or *never* (e.g. "None of the boxes is red."). The extension is the same for all of these quantifiers, but it differs in polarity - universal quantifiers refer to something *that is,* while null quantifiers refer to something *that is not*. Other quantifiers can be categorized as absolute/relative, and proportional/disproportional (Dik 1989; Langacker 1991; Zovko Dinkovic 2013). Absolute proportional quantifiers contain numbers (e.g. *five of the seven*), while relative proportional quantifiers do not refer to an exact number (e.g. *some of the five*). Absolute disproportionate quantifiers are numbers (e.g. *one*), and relative disproportionate quantifiers include words such as *many*, *much*, *few, little* and *some*, with no reference to a greater ensemble (e.g. "Not many men know how to repair a PC"). Semantic theory differentiates between first-order and higher-order quantifiers (McMillan, Clark, Moore, Devita and Grossman 2005). While first-order quantifiers denote an exact or approximate number (e.g. "At least four dots are red."), higher-order quantifiers refer to comparisons between two components (e.g. "Every other dot is red."). First-order quantifiers are related to numerical knowledge, and their processing does not employ working memory (Szymanik and Zajenkowski 2010).

As already mentioned, Croatian affirmative sentences with relative disproportional quantifiers, e.g. "*Neki avioni su sletjeli."* (Eng. "Some planes landed."), can be transformed into negations with first-order, absolute proportional null quantifiers, e.g. *none*, and into negations with relative disproportional quantifiers, e.g. *some did not*. A third option is to negate quantifiers into non-universal quantifiers, e.g. *not every*. The three negations differ in information they provide about quantity: while null quantifiers give precise information about zero quantity, the quantifier *some* is an existential first-order quantifier due to logical processing - in a sentence (e.g. "Some dots are red."), it can be interpreted as *at least one* (e.g. "At least one dot is red.") or,

in the case of negation, as *none* (e.g. "None of the dots are blue."), with just an approximate number of dots being specified in both cases (Schmidt and Thompson 2008; Zovko Dinkovic 2013). This is why *some* can be categorized as a relative disproportionate quantifier. Similarly, non-universal quantifiers, e.g. *not every,* are also characterized by the lack of precise information about quantity (Noveck 2009).

If the differences between negations and quantifiers that form them are taken into consideration, it seems reasonable to wonder whether all negations are processed as proposed by Kaup et al.'s (2005, 2006) two-step model. Previous research suggests that different types of negation might be processed differently. In their experimental study, Just and Carpenter (1971) reported shorter reaction times for quantifiers that focus attention on a larger subset or an entire set, e.g. *all* compared to *few*. This implies that quantifiers denoting small quantities are psychologically less preferred than universal quantifiers and quantifiers denoting larger quantities. The same would be expected for the relative disproportionate quantifier *some,* (e.g. "Some stars are colored."), which also refers to a smaller quantity, but does not specify the exact number. In an attempt to determine its focus of attention, the relative meaning of *some* becomes evident. Does it mean "One star is colored, but others are not.", or "Two stars are colored and two are not colored."? According to one view, the extension of the quantifier *some* ranges from more than zero to total or maximum, if the context implies that *some* is extended to the maximum, as in: "If John eats *some* of them cookies, he'll get fat." (Shetreet, Chierchia and Gaab 2014). The sentence suggests that there is an obvious context which also allows the following interpretation: "If John eats *all* of them cookies, he'll get fat.". This point of view can be described as logical or semantic. Another view, roughly described as pragmatic, suggests that the quantifier *some* is on a lower level in the scalar line of quantifiers (scalar implicatures) compared to the quantifier *all*, which is why its meaning cannot be extended to the maximum e.g. "Some people are parents." (Horn 1972; Levinson 2000). According to scalar implicatures, lower-level quantifiers are used to denote a certain quantity, and should not be extended to a higher level. Furthermore, Meyer (1970) suggests that statements with a relative disproportionate quantifier like *some* are verified with less difficulty because only one member of the group must match the statement. A similar model of first-order quantifier processing was proposed by Szymanik and Zajenkowski (2010) in their computational studies. According to the model, if one component is interpreted as false during sentence verification, the processing stops and the statement is declared non-valid.

This study is aimed at investigating the processing of sentences with different quantifiers. The first goal is to determine whether the processing of affirmative sentences with the universal quantifier *all* differs from the processing of affirmative sentences with the relative disproportional quantifier *some*. It is expected that reaction times will be shorter in the case of the universal quantifier, as proposed by Just and Carpenter (1971). Such results would not

confirm the predictions of Szymanik and Zajenkowski's (2010) computational study.

The second goal is to determine whether or not negations with different quantifiers are processed differently. For that purpose negations with the non-universal quantifier *not all,* the relative disproportional quantifier *some not,* and negative concord with the null quantifier *none* were investigated. To gain a better insight into the processing of negations, two sub-goals were set. Firstly, sentences with semantically similar meaning, but different quantifiers will be compared. To be more precise, relative disproportionate quantifiers such as *some not* (e.g. "Some stars are not colored.") and the non-universal quantifier *not all* (e.g. "Not all stars are colored.") are similar in meaning as they both refer to an unspecific number of objects, but they form different types of negation. Negation of the quantifier *some* ("Some stars are colored.") into *some not* ("Some stars are not colored.") forms sentential negation (Beukema 1999; De Clercq, Haegeman, and Lohndal 2012), while non-universal quantifiers like *not all* make constituent negation (Klima 1964; Noveck 2009; Zovko Dinkovic 2013). Secondly, the processing of sentences with relative disproportionate and non-universal quantifiers will be compared with the processing of negative concord, i.e. sentences with null quantifiers that provide precise information about quantity.

Finally, the third goal of this study is to compare sentences with both the affirmative and the negative form of the relative disproportionate quantifier *some*. According to previous research, affirmative sentences are processed faster and more accurately than negations (Cheng and Huang 1980; Clark and Chase 1972; Just and Carpenter 1971; Kaup et al. 2005; Kaup et al. 2006; Margolin and Abrams 2009), so it is hypothesized that affirmative and negative sentences will be processed differently, regardless of the quantifier used.

## 2. Method

### 2.1. Participants

The target sample consisted of 28 participants, 20 of which were female and 8 were male. They were students at the University of Zagreb and The Catholic University of Croatia (psychology; sociology).

The participants were native speakers of Croatian. Their age ranged from 20 to 30. One participant was excluded from the subsequent analysis due to longer reaction time (>5000 ms) and low accuracy. Participants volunteered to take part in the study and they were not paid for their participation. None of the participants reported problems, such as difficulties in language processing, neurological disorders or vision that could affect experimental results.

## 2.2. Materials

E-prime 2.0 was used to conduct a sentence-picture verification task. The participants responded using a keyboard, connected to a computer. Reaction time was measured in milliseconds. The task included 70 sentence-picture pairs, 10 of which were used in a test-trial and 60 in the experiment. There were five types of sentences, presented randomly in 12 repetitions. The sentences were categorized into five groups, depending on their polarity and quantifier type: affirmative sentences with universal quantifiers (AU), affirmative sentences with relative disproportional quantifiers (A-RD), negations with relative disproportional quantifiers (N-RD), negations with non-universal quantifiers (NU), and negations with null-quantifiers (N). The items of each group were presented as shown in Table 1.

**Table 1.** Types of quantifiers used in the experiment, English and Croatian version

| QUANTIFIER | ENGLISH | CROATIAN |
|---|---|---|
| Universal (AU) | *All stars are colored.* | *Sve zvijezde su obojane.* |
| Aff. Relative disprop. (A-RD) | *Some stars are colored.* | *Neke zvijezde su obojane.* |
| Neg. relative disprop. (N-RD) | *Some stars are not colored.* | *Neke zvijezde nisu obojane.* |
| Non-universal(NU) | *Not all stars are colored.* | *Nisu sve zvijezde obojane.* |
| Null (N) | *None of the stars are (not) colored.* | *Nijedna zvijezda nije obojana.* |

It is important to note that earlier research has found differences in the processing of the relative disproportional quantifier *some*. For example, if participants are given the following sentence: "Some stars are colored.", paired with a picture where all stars are colored, they can take either a logical or pragmatic approach. Participants who interpret the sentence pragmatically will judge the pair as incongruent, because the quantifier *all* was not used - *some* does not mean *all* (Spychalska 2011). Those who respond logically will judge the pair as congruent. The expected rate of incorrect answers predicts the dominance of the pragmatic interpretation: cca. 40% of logical compared to 60% of pragmatic answers (Hunt Politzer-Ahles, Gibson, Minai, and Fiorentino 2013; Noveck, 2001; Noveck and Posada 2003). Logical and pragmatic comprehension of sentences with the quantifier *some* was tested by giving different instructions to participants: one group were instructed to treat the quantifier *some* as *some and possibly all* and the other as *some but not all* (Bott and Noveck 2004; Noveck and Sperber 2007; Rips 1975). The results showed there were differences in the speed and accuracy of processing between the two

interpretations of *some,* in that *some but not all* was processed slower and with lower accuracy. To exclude the possibility of pragmatic interpretation, feedback on accuracy followed after each incorrect answer. Feedback was also given in the test trial, which consisted of four sentences with relative disproportional quantifiers and six additional sentences.

Pictures were randomly created using different symbols varying in color (blue or colorless). Sixteen different symbols were used in the experiment (heart, star, arrow, triangle, cube, square, round, asterisk, trapeze, roller, rhombus, ellipse, exclamation mark, pyramid, question mark and dot). Each picture consisted of three identical symbols of the same color; either they were all blue or they were all colorless. Each symbol was equally distributed across all groups of sentences. An example of a sentence-picture pair is shown in Figure 1.
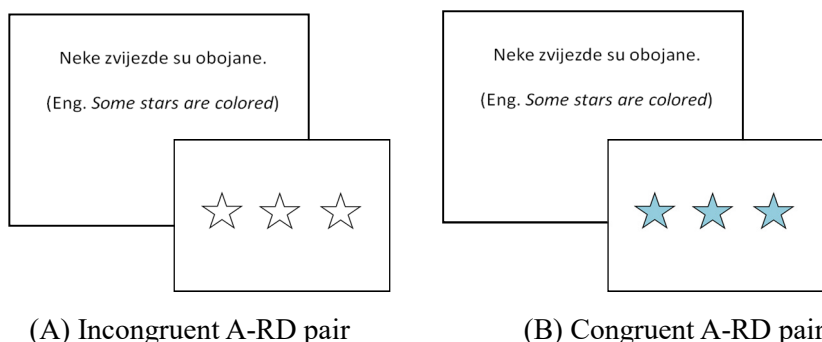


(A) Incongruent A-RD pair          (B) Congruent A-RD pair

**Figure 1.** An example of an incongruent and congruent pair (a picture and an affirmative sentence with a relative disproportionate quantifier)

## 2.3. Procedure

The participants were given a picture-sentence verification task. The study was conducted in Croatian. First, the participants were instructed to read a sentence presented on the computer screen. After reading the sentence, the participants were told to press the space bar. Then, a blank white screen was shown for 500 ms, followed by a picture that either matched (congruent pair) or did not match the sentence (incongruent pair). The participants responded by pressing the appropriate key on the keyboard (letters X and M, specially marked for the purpose of the study). The keys were randomized for each participant. Feedback was given only for incorrect answers. After the participants' response, a fixation mark (+) was shown for 300 ms to bring back their attention. The experiment lasted no longer than 15 minutes.

## 3. Results

### 3.1. Reaction time

The results were analyzed in STATISTICA 7. To see whether there was a significant effect of quantifier type and sentence-picture congruence on reaction time, an analysis of variance (ANOVA) with repeated measures on both factors was used. Only correct answers were included in the analysis of reaction time. No outliers were excluded from the analysis, and no transformation of the data was conducted.

The results showed a significant effect of quantifiers on reaction time $F$ $(4,104) = 26.06$, $p < 0.001$. According to Fischer's LSD post hoc test, affirmative sentences containing universal quantifiers ($M = 814.00$, $SE = 63.52$) were processed faster than affirmations with relative disproportionate quantifiers ($M = 968.08$, $SE = 62.10$), $p = 0.011$, as well as all types of negations: with relative disproportionate quantifiers ($M = 1270.93$, $SE = 89.68$), $p < 0.001$, non-universal quantifiers ($M = 1334.87$, $SE = 100.87$), $p < 0.001$, and null quantifiers ($M = 1086.05$, $SE = 73.09$), $p < 0.001$. Affirmative sentences with relative disproportionate quantifiers ($M = 968.08$, $SE = 62.10$) were processed faster compared to negative sentences: negations with relative disproportionate quantifiers ($M = 1270.93$, $SE = 89.68$), $p < 0.001$, non-universal quantifiers ($M = 1334.87$, $SE = 100.87$), $p < 0.001$, as well as null quantifiers ($M = 1086.05$, $SE = 73.09$), $p = 0.049$. Furthermore, reaction time for negations with null quantifiers was significantly shorter than for negations with relative disproportionate quantifiers ($M = 1270.93$, $SE = 89.68$), $p = 0.002$, and non-universal quantifiers ($M = 1334.87$, $SE = 100.87$), $p < 0.001$. No significant difference in reaction time between negations with non-universal ($M = 1334.87$, $SE = 100.87$) and relative disproportionate quantifiers ($M = 1270.93$, $SE = 89.68$), $p = 0.284$ was observed.

The results showed there was no effect of congruence on reaction time $F$ $(1,26) = 0.43$, $p = 0.516$. At the same time, there was a significant interaction between sentence/quantifier type and congruence $F$ $(4,104) = 4.36$, $p = 0.003$ (Figure 2.). Fischer's LSD post hoc test showed that affirmative sentences with universal quantifiers were processed faster when presented in congruent pairs ($M = 702.94$, $SE = 61.25$) compared to incongruent pairs ($M = 925.06$, $SE = 76.57$), $p = 0.003$. A similar tendency, though not statistically significant, was observed in congruent pairs with null quantifiers ($M = 1019.61$, $SE = 74.15$), which were generally processed faster than incongruent pairs ($M = 1152.48$, $SE = 90.46$), $p = 0.068$. The difference in reaction time between congruent and incongruent pairs in negations with relative disproportionate quantifiers was not statistically significant; however, there was a tendency towards faster processing of incongruent ($M = 1199.80$, $SE = 83.74$) compared to congruent pairs ($M = 1342.06$, $SE = 109.70$), $p = 0.051$. According to Fischer's LSD post hoc test, there was no significant difference in RT for congruent ($M = 959.80$, $SE = $

92.54) and incongruent ($M$ = 976.37, $SE$ = 58.52), $p$ = 0.819 affirmatives with relative disproportional quantifiers. Also, no difference was found between congruent ($M$ = 1377.44, $SE$ = 103.40) and incongruent ($M$ = 1292.30, $SE$ = 114.34), $p$ = 0.240, sentences with non-universal quantifiers.
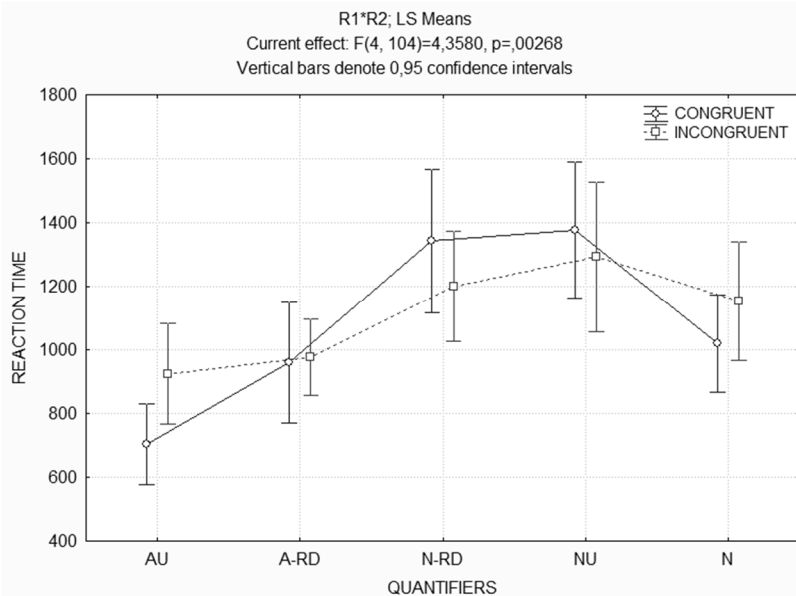


**Figure 2.** Interaction between sentences with different quantifiers and congruency

In general, the results of the analysis support previous findings and the two-step model of negation processing (Kaup et al. 2005; Kaup et al. 2006; Kaup, Zwaan and Lüdtke 2007; Kaup, Yaxley, Madden, Zwaan and Lüdtke 2007). All three types of negation exhibited longer reaction times compared to affirmative sentences. It seems that the processing of negations requires two steps, as proposed by the model, and that it does not depend on the type of negation or the quantifier. In support of previous research (e.g. Cheng and Huang 1980; Clark and Chase 1972; Kaup et al. 2006; Knoeferle, Urbach and Kutas 2009; Zwaan, Stanfield and Yaxley 2002), affirmative sentences with universal quantifiers were processed differently depending on sentence-picture congruency, with congruent pairs being processed faster than incongruent ones. Contrary to previous findings, according to which incongruent pairs exhibited shorter reaction time than congruent pairs (Cheng and Huang 1980; Clark and Chase 1972; Just and Carpenter 1971; Kaup et al. 2005; Kaup et al. 2007), the results of this study indicate that there is no significant difference between the processing of congruent and incongruent pairs in negations.

## 3.2. Accuracy

An ANOVA with repeated measures was used to investigate the effect of sentence/quantifier type and congruency on accuracy of answers. Both correct and incorrect answers were included in the analysis. The results showed there was a significant main effect of quantifier type on accuracy, $F(4,104) = 6.85$, $p < 0.001$. According to Fischer's LSD post hoc test, affirmative sentences with universal quantifiers ($M = 97.84$ %, $SE = 0.95$) were processed more accurately than affirmative sentences with relative disproportionate quantifiers ($M = 91.67$ %, $SE = 1.89$), $p = 0.021$. Also, they were processed with higher accuracy compared to negative sentences: negations with negative relative disproportionate quantifiers ($M = 86.11$ %, $SE = 2.29$), $p < 0.001$, non-universal quantifiers ($M = 86.11$ %, $SE = 2.56$), $p < 0.001$, and null quantifiers ($M = 91.36$ %, $SE = 2.16$), $p = 0.015$. Sentences with affirmative relative disproportionate quantifiers ($M = 91.67$ %, $SE = 1.89$) were processed more accurately than sentences with negative relative disproportionate ($M = 86.11$ %, $SE = 2.29$), $p = 0.037$ and non-universal quantifiers ($M = 86.11$ %, $SE = 2.56$), $p = 0.037$, but no significant difference was found between affirmatives containing relative disproportionate quantifiers and sentences with null quantifiers ($M = 91.36$ %, $SE = 2.16$), $p = 0.907$. Sentences with null quantifiers were processed more accurately compared to sentences with negative relative disproportionate ($M = 86.11$ %, $SE = 2.29$), $p = 0.048$ and non-universal quantifiers ($M = 86.11$ %, $SE = 2.56$), $p = 0.048$. There was no significant difference in accuracy of answers between sentences with negative relative disproportionate ($M = 86.11$ %, $SE = 2.29$) and non-universal quantifiers ($M = 86.11$ %, $SE = 2.56$), $p = 1.000$.

An ANOVA showed a significant main effect of congruency on accuracy of answers, $F(1,26) = 10.84$, $p = 0.003$. It seems that congruent pairs ($M = 87.65$ %, $SE = 1.42$) were processed less accurately than incongruent pairs ($M = 93.58$ %, $SE = 1.55$), $p = 0.003$. However, these results are highly affected by a significant interaction between congruency and sentence type, $F(4,104) = 2.57$, $p = 0.042$, as illustrated in Figure 3. Fischer's LSD post hoc test revealed a similar pattern for all types of negation. Incongruent pairs with relative disproportionate quantifiers ($M = 91.36$ %, $SE = 2.42$) were processed more accurately than congruent pairs ($M = 80.86$ %, $SE = 3.64$), $p = 0.001$. Also, accuracy was higher in incongruent pairs with non-universal quantifiers ($M = 90.74$ %, $SE = 2.57$) compared to congruent pairs ($M = 81.48$ %, $SE = 3.37$), $p = 0.003$. Negations with null quantifiers showed a similar pattern, with answers being more accurate when presented in incongruent ($M = 94.44$ %, $SE = 2.18$) than in congruent pairs ($M = 88.89$ %, $SE = 2.81$), $p = 0.042$. In affirmative sentences with relative disproportional quantifiers, no significant difference was observed between congruent ($M = 88.89$ %, $SE = 2.81$) and incongruent pairs ($M = 94.44$ %, $SE = 2.35$), $p = 0.067$, although there was a tendency towards the pattern found in negations. Finally, there was no significant difference between

congruent ($M = 98.77$ %, $SE = 0.86$) and incongruent pairs ($M = 96.91$ %, $SE = 1.55$), $p = 0.538$ in sentences with universal quantifiers.
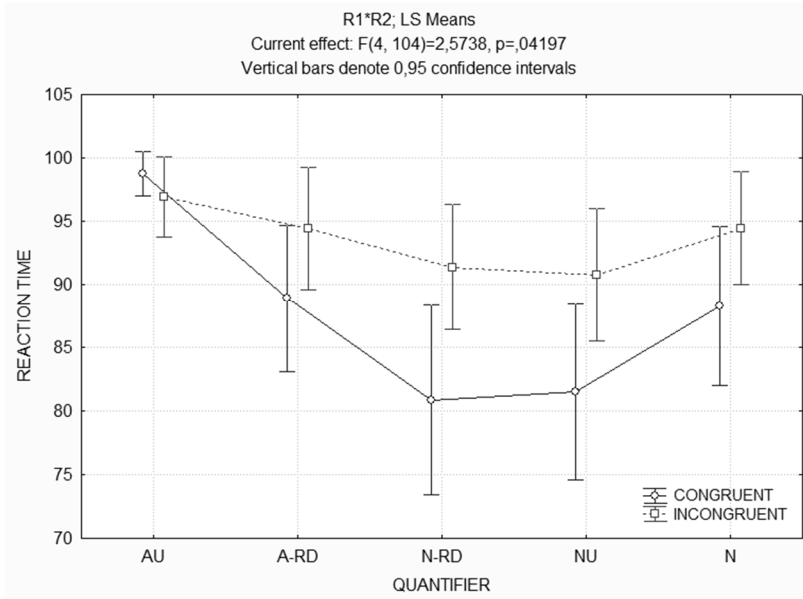


**Figure 3.** Interaction between quantifier type and congruency

The results of the analysis generally support previous findings (Just and Carpenter 1971; Margolin and Abrams 2009): answers were more accurate in affirmative sentences than in negations. The only exception was observed in the case of affirmatives with relative disproportional quantifiers and negations with null quantifiers, as no significant difference between the two was found. Although it seems logical to assume that congruent sentence-picture pairs are easier to process, research on negations has often reported negation-by-truth-value interaction (Just and Carpenter 1971; Kaup, Yaxley, Madden, Zwaan and Lüdtke 2007). The analysis of negations showed a similar pattern as reported by previous research, with higher accuracy in the case of incongruent pairs compared to congruent pairs.

The observed differences in reaction time and accuracy of answers do not indicate that the phenomenon called speed-accuracy trade off (SAT) took place (Fitts 1954; Fitts and Peterson 1964). Affirmative sentences were processed faster and more accurately compared to negative sentences, which indicates that negations require more steps during sentence comprehension than affirmatives. Also, sentences with null quantifiers were processed faster and more accurately than sentences with quantifiers denoting unspecified quantity. The difference in accuracy of answers between affirmative sentences with relative disproportionate quantifiers and affirmatives with universal quantifiers was

statistically non-significant; however, the latter proved to take more time to process.


## 4. Discussion

The main goal of this paper was to investigate the processing of affirmative sentences and negations with different quantifiers. Generally, the results support previous findings according to which affirmative sentences are processed faster (Cheng and Huang 1980; Clark and Chase 1972; Kaup et al. 2005; Kaup et al. 2006; Kaup, Zwaan and Lüdtke 2007; Kaup, Yaxley, Madden, Zwaan and Lüdtke 2007) and more accurately (Just and Carpenter 1971; Margolin and Abrams 2009) compared to negations. The results are consistent with the two-step model of negation comprehension. Positive sentences with universal quantifiers (e.g. "All stars are colored.") and affirmative sentences with relative disproportionate quantifiers (e.g. "Some stars are colored.") exhibited shorter reaction times, which can be explained by the fact that cognitive processing of affirmatives includes only one step. At the same time, the processing of negations, which took more time, includes two stages: they are processed as positive statements in the first step (*colored stars*), and negated in the second (*not colored stars*).

In addition to previous findings, a significant difference in reaction time and accuracy between affirmative sentences with different quantifiers was observed. Affirmative sentences with the universal quantifier "*all*" were processed faster and more accurately than affirmative sentences with the relative disproportional quantifier "*some*". These results are in line with the model which assumes that universal quantifiers focus attention on an entire set in an experimental task which is why they are easier to comprehend or more preferred (Just and Carpenter 1971) than quantifiers that refer to smaller quantities. Horn (1972) also postulates that quantifiers are arranged on a linguistic scale in terms of information they provide about quantity. On that scale, the quantifier "*all*" is superior to the quantifier "*some*", because the quantifier "*some*" provides less information about quantity. The relative disproportionate quantifier "*some*" refers to a smaller quantity with no information about the exact number (Zovko Dinkovic 2013). Its relativity becomes even more evident in an attempt to determine its focus of attention. Does "*some*" mean "One star is colored, but others are not.*"*, "Two stars are colored and two are not colored.*"* or even "Every star is colored.*"*? Previous studies show that a pragmatic interpretation of sentences with the quantifier "*some*" require a longer response time than a logical interpretation (Bott and Novec 2004; Glass and Holyoak 1974; Novec 2001; Noveck and Sperber 2007; Rips 1975). This could be due to the fact that there are two ways in which the quantifier "*some*" can be interpreted. But, as emphasized earlier, this was controlled by the methodology of the experiment. With this in mind, the results seem to indicate that there is an additional step in

the processing of sentences with the relative disproportional quantifier, which resulted in longer reaction time and lower accuracy.

The results also revealed significant differences in the processing of negations with different quantifiers: negations with the non-universal quantifier "*not all*", negations with the relative disproportional quantifier "*some not*" and negative concord with the null quantifier "*none*". No differences were found between sentences with semantically similar meaning but different quantifiers. Negations with the relative disproportionate quantifier "*some not*" and those with the non-universal quantifier "*not all*" had same reaction time and accuracy rate. These sentences are logically equivalent (Spychalska 2009) and semantically similar, but they differ in the type of quantifier used to convey meaning. However, their reaction time was longer compared to sentences with the null quantifier "*none*". According to the results, sentences with quantifiers that give unspecified quantitative information appear to be more difficult to process than those with non-universal quantifiers and precise quantitative information. These findings could suggest there is an additional step in the cognitive processing of sentences with relative quantifiers. In linguistic terms, the observed difference is not a result of a different form of negation, but rather the type of quantifier used. It could be that sentences with quantifiers denoting unspecific quantity, such as "Not all stars are colored*."* and "Some stars are not colored.", are first processed as affirmative sentences, while the second stage includes negation, and an additional step allows for re-checking the quantity.

Although a significant difference in the processing of different types of negation could be seen as a consequence of the type of quantifier involved, it seems that the polarity of a sentence has greater impact on sentence processing. For example, affirmatives containing the relative disproportional quantifier "*some*" are processed faster and more accurately than negations with the same quantifier. In line with the two-step processing model (Kaup et al. 2005; Kaup et al. 2006), the results of this study show that negations with relative disproportional quantifiers are first processed as affirmatives (e.g. "Some stars are colored."), with negation being added in the second step (e.g. "Some stars are not colored."). At the same time, the observed difference in the processing between affirmative sentences with universal quantifiers and affirmatives with relative disproportional quantifiers could indicate there is an additional step for re-checking the quantity.

Considering the two different lines of interpretation in the processing of "*some*", the results of this study could be explained by assuming there is an additional step in the processing. Evidence to support this was found in both affirmative sentences and negations. According to the experimental task (Figure 1), if only one star in a sentence with a relative disproportionate quantifier is colored, the sentence matched the picture. At the same time, for a sentence with a universal quantifier to match the picture, all stars had to be colored. Despite the fact that fewer stars had to be colored to match the picture, affirmative sentences with universal quantifiers were processed faster than affirmative

sentences with relative disproportionate quantifiers. This could imply that affirmatives with relative disproportionate quantifiers contain implicit negations, such as "*Some aren't*", which would require re-checking of a situational model created during sentence comprehension. It is thus argued that, in line with the Situational model of sentence comprehension, the processing of affirmative sentences with relative disproportionate quantifiers also require an additional stage in cognitive processing, termed "*quantifier-step*". According to this model, the stars are first processed as colored. In the second stage, a disproportionate quantifier makes an implicit suggestion that some stars may not be colored. Another example of such processing is a sentence with the quantifier "*few*"(e.g. "Few apples are good."). In terms of everyday speech, if we look at the basket full of apples, a sentence like "Few apples are good." does not only reveal that some apples are good, but also provides implicit negation, meaning that most of the apples are not good. Because of this implicit negation, the comprehension of the sentence "Few apples are good." could employ the second stage revision. The same process could underlie the comprehension of sentences with the quantifier "*some*".

As mentioned earlier, the processing of negative concord with a null quantifier takes more time than the processing of affirmative sentences, but less time compared to sentences with quantifiers denoting unspecified quantity. These differences also support the existence of the "quantifier-step", in which quantity is re-checked.

In further research, it would be interesting to investigate if there is a difference between the processing of negative concord and negations with universal quantifiers, and if the sentences would be processed according to the two-step model, or the processing would extend to the additional step due to the second negation. In Croatian, sentences that contain both universal quantifiers and negated verbs are not considered a part of the standard language (e.g. "All stars are not colored."). Rather, a negated adjective is used to form a sentence with one negation and a universal quantifier, as in "All stars are uncolored.". Because of this, experimental sentences should be selected carefully. Possible difficulties could arise from the fact that different processing underlies negated verbs and negated adjectives, which could lead to misinterpretation of the results. Still, it would be interesting to see how different sentences with a single negation are processed, as well as if a difference between double negation and negative concord processing would be found.

## 5. Conclusion

The results of the study show there is a significant difference in the processing between two types of affirmative sentences: sentences with universal quantifiers were processed faster and with higher accuracy rate compared to sentences with relative disproportionate quantifiers. In negative sentences, the processing of

negations with relative disproportional quantifiers, non-universal quantifiers and null quantifiers required less time and was more accurate than affirmative sentences. These findings are in line with the predictions of the two-step model, which postulates that negations are processed in the second step, by negating the affirmative mental model from the first step. However, it seems that the processing of negative sentences depends on the quantifiers used to form negation: the processing of negations with null quantifiers requires shorter reaction time and is more accurate compared to negations with relative disproportional quantifiers and non-universal quantifiers. This implies that quantifiers that do not provide specific information about quantity require an additional step in cognitive processing, due to the re-checking of quantity.

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