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**One can be some but some cannot be one:
ERP correlates of numerosity incongruence are different for singular
and plural**

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45**Abstract**

Humans can communicate information on numerosity by means of number words (e.g. *one hundred, a couple*), but also through Number morphology (e.g. through the singular vs. the plural forms of a noun). Agreement violations involving Number morphology (e.g. **one apples*) are well known to elicit specific ERP components such as the Left Anterior Negativity (LAN); yet, the relationship between a morphological Number value (e.g. singular vs. plural) and its referential numerosity has been scantily considered in the literature. Moreover, even if agreement violations have been proved very useful, they do not typically characterise the everyday language usage, thus narrowing the scope of the results.

In this study we investigated Number morphology from a different perspective, by focusing on the ERP correlates of congruence and incongruence between a depicted numerosity and noun phrases. To this aim we designed a picture–phrase matching paradigm in Italian. In each trial, a picture depicting one or four objects was followed by a grammatically well-formed phrase made up of a quantifier and a content noun inflected either in the singular or in the plural. When analysing ERP time-locked to the content noun, plural phrases after pictures presenting one object elicited a larger negativity, similar to a LAN effect. No significant congruence effect was found in the case of the phrases whose morphological Number value conveyed a numerosity of one. Our results suggest that incongruence elicits a negativity (LAN-like) independently from the grammaticality of the utterances and irrespective the P600 component; 2) the reference to a numerosity can be partially encoded in an incremental way when processing Number morphology; and, most importantly, 3) the processing of the morphological Number value of plural is different from that of singular as the former shows a narrower interpretability than the latter.

Keywords: Number morphology, ERP, LAN, singular, plural.

1. Introduction

The first thing that typically comes to mind when speaking of numerical abilities is probably performing calculation. We are so accustomed to counting and estimating that we hardly ever pay attention to how often we resort to basic numerical abilities in everyday life. Even our linguistic choices would not be effective without basic numerical reasoning; indeed, the pertinence of a singular form (e.g. *apple*) instead of a plural form (e.g. *apples*) strictly depends on the numerosity of the relevant referent. A great body of the literature has claimed that numerical reasoning stems from a subset of non-verbal numerical cognitive and phylogenetically ancient skills with which human and non-human animal species are endowed soon after birth in order to behave successfully (Cantlon & Brannon, 2007; Dehaene, 2011; Rugani, Vallortigara, Priftis, & Regolin, 2015; Spelke, 2000; Starr, Libertus, & Brannon, 2013). Numerical abilities as well as abilities concerning naïve physics, space and motion have been argued to be part of the core knowledge systems which would allow human and non-human animal species to represent the most important aspects of their environment (Carey, 2009; Spelke, 2000). Recently, it has been proposed that humans have also developed enhanced communicative systems, i.e. languages, to share information coming from mental experiences, and from the core knowledge systems in particular (e.g. Corballis, 2017). Indeed, if core knowledge information is biologically fundamental, its prompt communication must be in some way advantageous. Interestingly enough, core knowledge information would be so

1 relevant to shape the core structure of human languages (Bickel, Witzlack-Makarevich, Choudhary,
2 Schlesewsky, & Bornkessel-Schlesewsky, 2015; Christiansen & Chater, 2008; Franzon, Zanini, &
3 Rugani, 2018; Strickland, 2017). To what extent is this true for numerical knowledge? How does
4 numerical knowledge shape language grammars and influence linguistic processing?
5 The great majority of the studies investigating the relationship between numerical knowledge and
6 its encoding into language have taken into consideration the lexical level, mainly focussed on
7 quantifiers and number words (e.g. Butterworth et al., 1999; Carey, 2004; Clark & Grossman, 2007;
8 Gelman & Gallistel, 2004; Gordon, 2004; Lipton & Spelke, 2003; Ochtrup et al., 2013; Rath et al.,
9 2015; Salillas, Barraza, & Carreiras, 2015; Troiani, Peelle, Clark, & Grossman, 2009). It has been
10 shown that speakers of languages without number words do master non-verbal numerical skills (e.g.
11 Butterworth, Reeve, Reynolds, & Lloyd, 2008; Pica, Lemer, Izard, & Dehaene, 2004), being these
12 latter independent from the verbal ones, and that number words are dissociated from other lexical
13 categories (Bencini et al., 2011; e.g. Semenza et al., 2007). However, the information about
14 numerosity can be expressed into the language without relying on number words by means of
15 Number morphology, which systematically encodes it into different signs (e.g. *cat* vs. *cats* in
16 English). It has been estimated that at least the 90.8% of the languages reported in the WALS
17 (Dryer & Haspelmath, 2013) have a grammatical device to encode nominal plurality (Dryer, 2013).
18 The grammaticalised elements conveying the possible morphological Number values (often singular
19 and plural) are mostly phonologically short (e.g. *-s* in English for the plural) and mandatorily
20 expressed (i.e. all nouns or all the nouns belonging to a certain category such as animate or
21 countable nouns must be inflected for Number; among others see Dressler, 1989). In other words,
22 Number morphology is one of the most exploited devices throughout human languages to readily
23 communicate basic information about the numerosity of the referential world. These peculiarities of
24 Number morphology make intriguing the investigation of the processing related to it. For example,
25 children who speak languages displaying morphological Number values (e.g. singular, plural, dual)
26 have been shown to acquire the relevant number words (such as *one* or *two*) earlier than children
27 who speak languages without morphological Number values (Almoammer et al., 2013; Marušič et
28 al., 2016; Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007). A study conducted on
29 German by Roettger and Domahs (2015) reported an effect similar to SNARC (spatial-numerical
30 association of response codes) related to morphological Number in performing a series of
31 behavioural tasks. The authors found that words inflected in the singular had a relative left-hand
32 advantage and words in the plural a relative right-hand advantage. This finding seems to point to the
33 fact that quantity representation is accessed while processing morphological Number. In a fMRI
34 study on adult Spanish speakers, Carreiras and colleagues (2010) found increased activation of the
35 right superior parietal gyrus and of the right intraparietal sulcus only in conditions tackling the
36 morphological Number, but not in conditions dealing with other morphological features such as
37 Gender; significantly, the activation of these areas was found to be associated with non-verbal
38 numerosity processing (Butterworth et al., 1999; Dehaene, Piazza, Pinel, & Cohen, 2003; Pinel,
39 Piazza, Le Bihan, & Dehaene, 2004).

40 Yet, Number morphology *per se* and its link with numerosity have been scantily considered in
41 experimental studies, especially when compared with the long-standing tradition of works
42 investigating the mere functional facet of Number as a feature to perform agreement (*the cat meows*
43 vs. **the cat meow*). As observed by Molinaro, Barber and Carreiras (2011) in their review on ERP
44 findings as for agreement processing, “although a large number of papers have been devoted to
45 Number agreement, no study until now has focused on the qualitative distinction between the values

1 that express Number” (Molinaro et al., 2011: 926). Actually, since pioneer ERP studies, Number
2 agreement has been widely explored (e.g. Friederici, 1995; Hagoort, Brown, & Groothusen, 1993;
3 Kutas & Hillyard, 1983; Osterhout & Mobley, 1995). Typically, participants were asked to
4 passively read or listen to grammatical and ungrammatical sentences (or phrases); as an alternative,
5 they were asked to express grammaticality judgments or answer comprehension questions after
6 having read/heard each sentence (or phrase). In a seminal study on English, Kutas and Hillyard
7 (1983) contrasted syntactic and semantic violations in a comprehension task. They found that
8 subject-verb Number agreement violations elicited a negative peak (Left Anterior Negativity, LAN)
9 in electrical brain activity between 200 and 500 ms in anterior zones after stimulus presentation. In
10 a study on Dutch using a passive reading task, Hagoort et al. (1993) reported a P600 effect, i.e. a
11 posterior positive peak occurring 600 ms after stimulus presentation, in response to the same type of
12 agreement violations.

13 The LAN effect alone, the P600 effect alone or the LAN-P600 pattern have been reported in most
14 of the later studies (e.g. Barber & Carreiras, 2003, 2005; Barber, Salillas, & Carreiras, 2004; De
15 Vincenzi et al., 2003; Kaan, 2002; Silva-Pereyra & Carreiras, 2007), even in studies involving other
16 morphological features such as Gender (e.g. Caffarra, Janssen, & Barber, 2014), and their presence
17 and modulation may depend on the type of the stimuli involved. For example, Barber and Carreiras
18 (2005) found that Number violations in adjective-noun agreement elicited an N400 effect (which is
19 typically found in tasks involving semantic violations) while an additional LAN effect was
20 triggered in the determiner-noun context; in addition, when the same violations were presented in a
21 sentence context, they resulted in a LAN-P600 pattern. Interestingly enough, it has been shown that
22 the LAN component is generally not triggered when morphological Number values are not
23 conveyed at the morpho-phonological level: in a study on Italian, Molinaro, Vespignani, Zamparelli
24 and Job (2011) recorded the LAN in the subject-verb disagreement condition where the numerosity
25 of the subject was morphologically specified (as in **I ragazzi.PL corre.SG* ‘the boys runs’), but not
26 where it was only syntactically driven (as in **Il ragazzo.SG e la ragazza.SG corre.SG* ‘The boy and
27 the girl runs’). The LAN component has not been found also when the two elements involved in the
28 Number agreement relation respectively belong to two different clauses; in fact, it seems that the
29 intra-sentence domain is mostly relevant to morphological Number cues (e.g. Kaan, Harris, Gibson,
30 & Holcomb, 2000; Kaan & Swaab, 2003; Münte, Szentkuti, Wieringa, Matzke, & Johannes, 1997).
31 The consistency in findings across most of the studies had led to interpret the LAN component as an
32 index of difficulties in the early stages of the syntactic processing focused on morphological cues
33 (e.g. Friederici, 1995, 2002; 2011, Hagoort, 2005; Ullman, 2001). Such view is not fully embraced
34 by many scholars who instead explained the LAN component as an index of working memory
35 operations generally involved in language processing (Fiebach, Schlesewsky, & Friederici, 2001;
36 King & Kutas, 1995; Kluender & Kutas, 1993). More recently and more generally, the
37 interpretation of the LAN and the P600 components as indexes of processing of high-level linguistic
38 features has been criticised. For example, the P600 has been traditionally linked to a later
39 integration of the processed constituent at the sentence level (e.g. Barber, Salillas, & Carreiras,
40 2004; Kaan, Harris, Gibson, & Holcomb, 2000; Kaan & Swaab, 2003); yet, such view has been
41 increasingly challenged by researchers claiming that P600 effects may correlate with violations
42 other than purely syntactic and linguistic ones since the P600 might be related to the P300 family
43 and to general cognitive processing as context-updating (e.g. Bornkessel-Schlesewsky &
44 Schlesewsky, 2008; Sassenhagen, Schlesewsky, & Bornkessel-Schlesewsky, 2014; see also Van
45 Petten & Luka, 2012). Similarly, the LAN component has been interpreted as an illusion effect

1 resulting from individual differences in brain responses between N400 and P600 effects rather than
2 an autonomous morpho-syntactic component (Tanner, 2015; Tanner & Van Hell, 2014). Molinaro
3 and colleagues (2015; 2011) do not agree with such view claiming for an independent LAN
4 component detectable event without the P600. The authors linked the reliability of the LAN effect
5 to the type of the morpho-syntactic structure at issue: the more a morpho-syntactic mismatch is
6 unambiguously detectable as ungrammatical, the higher the probability to elicit a LAN effect. In
7 this sense, the LAN could be considered an index of morpho-syntactic expectation in addition to an
8 index of difficulty in integrating morpho-syntactic anomalies in the context.

9 The fact that almost all the ERP studies on morphological Number have exploited violation
10 paradigms does not allow to disentangle between these two interpretations of the LAN effect. Can
11 the LAN be found without resorting to violation paradigms and interpreted as an index of morpho-
12 syntactic expectation independently from the detection of grammatical anomalies? In this regard, it
13 is worth noticing that another ERP component, the N400, usually linked to the detection of
14 semantic anomalies, is modulated also by contextually generated expectancies irrespectively from
15 purely agreement or semantic violations (e.g. DeLong, Urbach, & Kutas, 2005). Anticipatory
16 processing was found in many cognitive domains, and the grammars of human languages do not
17 represent an exception to this. For example, it is well known that features involved in agreement
18 rules, among which morphological Number, are systematically used to predict upcoming linguistic
19 and/or visual materials as reported in several eye-tracking studies (Altmann & Kamide, 2007; for a
20 review see Huettig, Rommers, & Meyer, 2011). And yet the relationship between morphological
21 Number values, the denoted numerosity and their role in anticipatory processing is comparatively
22 an under-researched topic in the ERP field.

24 1.1 The present study

25 The present ERP study intends to help filling the gap in the literature on morphological Number by
26 investigating the time course of the processing of singular and plural, without exploiting a
27 grammatical violation paradigm. Indeed, the goal is to investigate the congruence between
28 morphological Number values (i.e., singular/plural) and the respective denoted numerosity (i.e.
29 figure of one object or of several objects) rather than a grammatical relational property such as
30 Number agreement. To this aim, we designed a paradigm in which a picture representing one or
31 more objects was followed by a noun phrase inflected in the singular or in the plural. Participants
32 had to judge whether the noun phrase appropriately described the preceding picture, namely
33 whether it was congruent or not.

34 The task was administered to Italian adult speakers as Italian language mostly displays a
35 phonologically transparent Number morphology. Most importantly, Italian has two quantification
36 expressions, *alcuni* ‘some’ + *noun.PL* and *qualche* ‘some’ + *noun.SG*, both of which refer to a
37 plural numerosity; yet, nouns agree in the plural with *alcuni*, but in the singular with *qualche*. This
38 peculiarity of Italian helps to disentangle effects due to the morpho-phonological form of a
39 morphological Number value from effects due to its referential meaning. Finally, the long tradition
40 in electrophysiological studies on Italian Number (dis)agreement allows comparability between the
41 previous and the present results as far as the interpretation of the ERP components is concerned.

42
43 We hypothesised that ERP responses were more prone to being modulated by the referential
44 meaning effects than morpho-phonological ones. Given previous evidence on partial incremental
45 processing of language (Urbach & Kutas, 2010), we expected to be able to elicit more negative

1 LAN or N400 components in the incongruent condition as compared to the congruent one. As this
2 is the first study to our knowledge, to perform this kind of investigation, we did not have specific
3 expectations on the difference between singular and plural.
4

5 6 **2. Method**

7 8 **2.1 Participants**

9 Twenty-seven young adult native speakers of Italian took part to the study as volunteers. One
10 participant was excluded from the analysis because of a misunderstanding of the task instructions,
11 discovered in a de-briefing after the experiment. Thus, the final analyses included a total of twenty-
12 six participants (females = 17; mean age = 24.5; min age = 20; max age = 32; SD = 2.98). All
13 participants were right-handed, had normal or correct-to-normal vision, and had no reported history
14 of reading or learning disorders. All participants signed a written informed consent before taking
15 part to the study. The experiment was approved by the Local Ethics Committee.
16

17 **2.2 Procedure**

18 Participants were tested in a dimly lit, quiet room. They were asked to complete a picture-phrase
19 matching task, performed on a computer screen. The task (an adaptation from Gastaldon et al.,
20 2016), was delivered with the E-prime software (Psychology Software Tools, 1999, Pittsburgh,
21 PA). Each trial consisted of the following sequence: first, a fixation cross appeared in the centre of
22 the screen (1000 ms); afterwards, a picture showed up (1000 ms) followed by a short blank screen
23 for 200 ms and then by two words. The first word was displayed for 300 ms, followed by a blank
24 screen (200 ms), and the second word was displayed for 300 ms. The words were followed by
25 another blank screen with a random duration between 1000 or 1500 ms, after which two response
26 words (True and False) appeared at the right and at the left side of the screen. The participants were
27 asked to respond whether the two-words sequence described appropriately the preceding picture,
28 without any time pressure. The position of the response words (i.e. True/False) as well as that of the
29 corresponding response keys were always the same for each participant, but counterbalanced across
30 participants. The trial procedure is illustrated in Figure 1. All stimuli subtended at most 5 degrees
31 on the horizontal plane, to avoid excessive eye movements. Five practice trials were administered
32 before the beginning of the experiment to familiarise with the task. The overall task lasted about 45
33 minutes. The task included twelve breaks, and so the participants had the opportunity to rest every 5
34 minutes. Prior to the beginning of the task, we also recorded a 5-minute session of resting-state, not
35 further analysed in the present study.
36
37

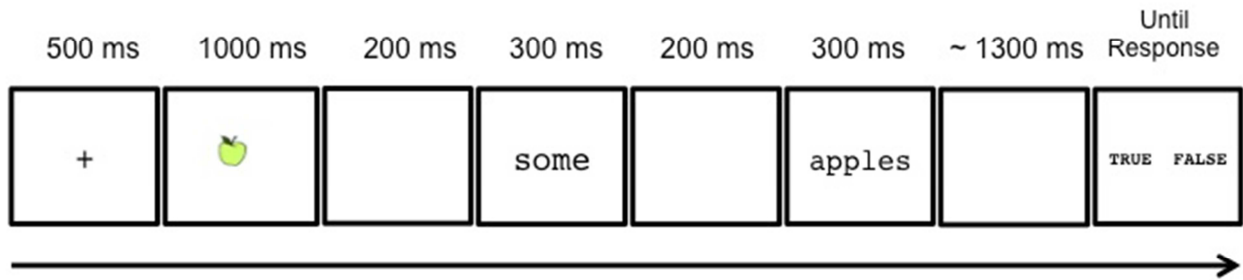


Figure 1. **Task Design.** The picture shows the design of the task employed. All trials followed the depicted sequence. After a fixation cross a picture was displayed, followed by two-word phrases presented in a word-by-word fashion. Participants had to respond if the phrases corresponded to the presented picture by pressing two buttons associated with TRUE/FALSE response (FALSE, in the depicted example). There was no time pressure for the response.

2.3. Materials

The linguistic stimuli of the experiment consisted in phrases made up of quantifier-noun pairs. We decided to present nouns modified by a quantifier rather than bare nouns to control for the interpretation of the morphological Number values. In fact, according to many theoretical linguistic accounts, in very particular cases singular and plural markings can alternately convey a reading of general Number, that is a Number value that does not refer to any numerosity with respect to a countable entity (Corbett, 2000). In Italian, the general Number can surface syncretically to the form of singular as in the expression *qualche gatto* ‘some cats; lit. some cat.SG’ where the morpheme *-o* of the noun *gatto* does not mean “one”, but the plural meaning is conveyed by the quantifier *qualche* (among others, Acquaviva, 2013; Franzon, Zanini, & Rugani, 2018; Zamparelli, 2008). Thus, we selected three quantifiers:

- *one+noun.SG*: the nouns were inflected in the singular and linked with a numerosity of one since they were preceded by the numeral quantifier ‘one’ (e.g. *una mela* ‘one apple’). This latter can surface in Italian with a masculine (*un/uno*) or feminine (*una*) singular marking.
- *some+noun.PL*: the nouns were inflected in the plural and linked with a numerosity greater than one denoting few entities since they were preceded by the quantifier ‘some’ (e.g. *alcune mele* ‘some apples’). This latter can surface in Italian with a masculine (*alcuni*) or feminine (*alcune*) plural marking.
- *some^o+noun.SG*: the nouns bore a marking which is singular from a morpho-phonological point of view. Yet, they were preceded by the quantifier *qualche*, meaning ‘some’, and thus their morpho-phonological marking of singular must be interpreted as a general Number linked to an interpretation of plurality (e.g. *qualche mela* ‘some apples’, lit. ‘some apple’). It is worth noticing here that this quantification expression is perfectly grammatical in Italian and that both *alcuni/e* and *qualche* refer to a plural numerosity with a paucal reading (e.g. Zamparelli,

2008). We decided to add this condition besides the previous ones since all together are useful to disentangle effects due to the morpho-phonological form of a Number value (singular vs. plural) from effects due to the semantic feature linked with the Number value in a given phrase context (singularity vs. plurality).

In the rest of the manuscript we refer to the variable associated with the three levels *one+noun.SG*, *some+noun.PL*, and *some^o+noun.SG* as *Semantic feature of the morphological Number*¹ (henceforth: *Semantic F-Number*). Importantly, with this label we classify the conditions according to the number value at the phrase level (i.e., the combination of quantifier and content word), and not a single-word level.

The stimuli were created to be matched, as much as possible, for length and frequency. We took into account, in particular, the orthographic length of the content nouns (e.g. the length of *mela*, ‘apple’), and the orthographic length and the frequency of the whole phrases (e.g. *una mela* ‘one apple’). Length was calculated as number of graphemes (i.e. letters), whereas frequency was calculated as log-transformed frequency, collected from the itWaC corpus (Baroni, Bernardini, Ferraresi, & Zanchetta, 2009). Considering the content nouns, stimuli were matched for length and frequency across all conditions. Considering the phrases (quantifier plus content word), the condition with *one+noun.SG* was always more frequent than the conditions *some+noun.PL* and *some^o+noun.SG*. It was not possible to match on the phrase frequency given the intrinsic properties of distribution of these quantifiers in Italian. They were also unbalanced in terms of phrase length as the quantifier *uno/a* ‘one’ was always two or three letters long, the quantifier *qualche* ‘some^o’ was always seven letters long, and the quantifier *alcuni/e* ‘some’ was always six letters long. In each phrase, all content nouns referred to concrete, countable, and non-animate objects. We selected two pictures for each noun, representing either one single object or four instances of that object (we choose four objects as this is a numerosity possibly associated with a reference of paucal in language grammars; see, among others, Corbett, 2000). The drawings in the pictures were arranged to avoid any kind of effect due to structural composition. In particular, in the picture representing one single object the drawing was decentralised to minimise possible effects due to the less space occupied by the object in comparison with that occupied by four objects. In the pictures representing four objects the drawings were arranged in pseudo-random positions.

Each picture-to-phrase matching could be congruent (e.g. a picture of four apples followed by the phrase ‘some apples’) or incongruent. The mismatches concerned either the numerosity of the objects (e.g. a picture of one apple followed by the phrase ‘some apples’) or the referential objects themselves (e.g. a picture of one orange followed by the phrase ‘one sponge’). The inclusion of a condition with a mismatch between the depicted object and the last word (i.e. the noun) was crucial to ensure that participants processed the entire phrase and not only the first word. To avoid excessive repetition of stimuli during the task we used separate lists of stimuli for the contrast on

¹ In Italian, it is not always possible to interpret a morphological Number value independently from the context (for example, the Number value of singular can convey both singularity or mass interpretation and only the pragmatic or syntactic context disambiguate from these two meanings (della pizza “some pizza” vs. una pizza “a pizza”). In the experimental conditions included we constrained the interpretation of the morphological values in the experimental design both in the prototypical cases (*one+noun.SG*, *some+noun.PL*) and in the non-prototypical one (*some^o+noun.SG*). Importantly, the contrast does not tackle the referential level, but the morphological (linguistic internal) level, as it concerns the link between the form of a morpheme and its meaning. For this reason, we labelled the condition “Semantic feature of the morphological Number”.

1 the denoted numerosity and for the contrast on the denoted referents. We did not include a condition
2 with both types of incongruence. At the end each combination of experimental variables included
3 30 stimuli for a total of 360 experimental stimuli.
4 Summarising, in creating the stimuli the following variables were taken into account: *Contrast*
5 (denoted and depicted numerosity vs. denoted and depicted objects); *Semantic F-Number*
6 (*one+noun.SG* vs. *some+noun.PL* vs. *some^o+ noun.SG*), *Congruence* (congruent trial vs.
7 incongruent trial). The number of stimuli and the combinations are summarized in Table 1, while
8 properties on the psycholinguistic variables taken into account are reported in Table 2













Condition	Picture numerosity	Presented phrase	Phrase example	Numerosity at phrase level /congruence	Numerosity at morphological level/congruence	N° of Stimuli
Depicted Numerosity		<i>one+noun.SG</i>	“one apple” (una mela)	SG / True	SG / True	30
		<i>one+noun.SG</i>	“one apple” (una mela)	SG / False	SG / False	30
		<i>some+noun.PL</i>	“Some apples” (alcune mele)	PL / False	PL / False	30
		<i>some+noun.PL</i>	“Some apples” (alcune mele)	PL / True	PL / True	30
		<i>Some°+noun.SG</i>	“Some° apple” (qualche mela)	PL / False	SG / True	30
		<i>Some°+noun.SG</i>	“Some° apple” (qualche mela)	PL / True	SG / False	30
Depicted Object		<i>one+noun.SG</i>	“one orange” (una arancia)	SG / True	SG / True	30
		<i>one+noun.SG</i>	“one sponge” (una spugna)	SG / True	SG / True	30
		<i>some+noun.PL</i>	“some oranges” (alcune arance)	PL / True	PL / True	30
		<i>some+noun.PL</i>	“some sponges” (alcune spugne)	PL / True	PL / True	30
		<i>Some°+noun.SG</i>	“some° orange” (qualche arancia)	PL / True	PL / False	30
		<i>Some°+noun.SG</i>	“some° sponge” (qualche spugna)	PL / True	PL / False	30

Table 1. Experimental stimuli. The table reports the experimental stimuli. The first column reports the task contrast (on Depicted Numerosity or on Depicted Object); the second column reports an example of the picture displayed. The third column the type of quantifier (and its label throughout the manuscript). The fourth column reports an example of the object noun. The fifth column reports the congruence between the Picture and the quantifier-content word pairs (that was also the response required by the participant). The sixth column reports an example of a trial, that included a whole combination of variable levels. Each trial consisted of a picture followed by two words (Italian original version enclosed in parentheses). The seventh column report reports the total number of stimuli included for each combination of variable levels.

1

PHRASE- LENGTH

	mean	sd	median	min	max	skewness	kurtosis	Q1	Q3
Numerosity contrast - some+noun.PL	13.13	1.21	13	11	16	0.76	0.04	12	14
Numerosity contrast - some ^o +noun.SG	14.1	1.17	14	12	17	0.55	-0.41	13	15
Numerosity contrast - one+noun.SG	9.7	1.2	9	8	12	0.46	-0.82	9	11
Object contrast - some+noun.PL	12.85	1.05	13	11	15	-0.05	-0.95	12	14
Object contrast - some ^o +noun.SG	13.77	1.06	14	12	16	0.13	-0.7	13	14.25
Object contrast - one+noun.SG	9.53	1.08	10	7	11	-0.6	-0.07	9	10

CONTENT WORD - LENGTH

	mean	sd	median	min	max	skewness	kurtosis	Q1	Q3
Numerosity contrast - some+noun.PL	6.13	1.21	6	4	9	0.76	0.04	5	7
Numerosity contrast - some ^o +noun.SG	6.1	1.17	6	4	9	0.55	-0.41	5	7
Numerosity contrast - one+noun.SG	6.1	1.17	6	4	9	0.55	-0.41	5	7
Object contrast - some+noun.PL	6.1	1.17	6	4	9	0.55	-0.41	5	7
Object contrast - some ^o +noun.SG	5.85	1.05	6	4	8	-0.05	-0.95	5	7
Object contrast - one+noun.SG	5.77	1.06	6	4	8	0.13	-0.7	5	6.25
	5.93	0.99	6	4	8	-0.28	-0.84	5	7

PHRASE - FREQUENCY

	mean	sd	median	min	max	skewness	kurtosis	Q1	Q3
Numerosity contrast - some+noun.PL	2.97	1.35	2.92	1.1	7.07	0.97	0.9	1.79	3.76
Numerosity contrast - some ^o +noun.SG	3.34	1.34	3.11	1.1	6.94	0.76	0.44	2.4	3.93
Numerosity contrast - one+noun.SG	6.66	1.97	6.94	0	10.88	-1.27	3	6.06	7.76
Object contrast - some+noun.PL	2.79	1.46	2.77	0	5.39	0.15	-1.05	1.55	3.62
Object contrast - some ^o +noun.SG	2.81	1.38	3.22	0	5.13	-0.6	-0.4	2.05	3.72
Object contrast - one+noun.SG	7.3	1.69	7.48	0	9.67	-2.49	8.97	6.85	8.16

CONTENT WORD - FREQUENCY

	mean	sd	median	min	max	skewness	kurtosis	Q1	Q3
Numerosity contrast - some+noun.PL	8.78	0.99	8.71	6.9	11.95	0.78	1.83	8.28	9.13
Numerosity contrast - some ^o +noun.SG	8.99	1.15	8.95	6.93	12.59	0.84	1.45	8.21	9.55
Numerosity contrast - one+noun.SG	8.99	1.15	8.95	6.93	12.59	0.84	1.45	8.21	9.55
Object contrast - some+noun.PL	8.63	1.24	8.41	6.88	11.12	0.31	-1.04	7.74	9.69
Object contrast - some ^o +noun.SG	9.5	1.2	9.44	7.2	12.13	0.46	-0.52	8.69	10.25
Object contrast - one+noun.SG									

2

3 **Table 2. Psycholinguistic variables.** The table reports the means, standard deviations, median,
4 minimum, maximum, skewness, kurtosis, first quartile and third quartile for the psycholinguistic
5 variables taken into account. Details on statistical comparison between stimuli are reported in
6 Supplemental Data.

7

2.4 EEG data recording

EEG signal was recorded from 28 active electrodes embedded in an elastic cap, arranged according to the 10/20 system (Brain products, Acticap). Each electrode was referenced on-line to the left earlobe. Three additional electrodes were used to monitor eye movements and blink, with two electrodes placed near the outer corner of the eyes (*external canthi*) and one placed in a pupil centred position, under the left eye. The impedance of each electrode was kept lower than 10 K Ω throughout the recording. The following electrodes were included: Fp1, Fp2, Fz, F3, F4, F7, F8, FC1, FC2, FC5, FC6, C3, C4, Cz, T7, T8, CP1, CP2, CP5, CP6, P3, P4, P7, P8, Pz, O1, O2, Oz. The EEG signal was amplified by using BrainAmp amplifiers with hardware high-pass of 0.1 and with a sampling rate of 500 Hz.

2.5 EEG data analysis

EEG data were pre-processed with Brainstorm MATLAB toolbox (Tadel et al., 2011, March 2015 version). In the pre-processing phase, first we applied a high-pass filter at 0.5 Hz to the continuous data. Afterwards, we used Independent Component Analysis (ICA) to remove artifacts with well-defined topography: blinks and the power line noise at 50 Hz. From the ICA corrected continuous data, we extracted epochs time-locked to the onset of the first word, ranging from -3000 ms to 2000 ms after stimulus. Trials containing excessive artifacts were rejected in this phase after visual inspection. From these initial epochs, smaller epochs around the first word (the quantifier) and the second word (the content noun) were extracted, with a time window spanning from -500 pre stimulus to 1500 ms post stimulus, baseline corrected to the mean value of 100 ms preceding the stimulus. We calculated separately an average for each condition, including only trials with a correct behavioural response. On these final ERP averages, a low-pass filter at 40 Hz was applied. The mean number of accepted trial for each condition was 94% (mean accepted trials 28.2 out of 30 for condition), with no appreciable differences across conditions (number of accepted trials separate for condition ranged from 93% to 95%). Statistical analysis and graphics were made with R (R core Team, 2016) and with the two R packages *erpR* (Arcara & Petrova, 2017), and *ez* (Lawrence, 2015).

We focused the statistical analysis on the ERPs time-locked to the second word (the content noun). To this aim we conducted two different analyses, ANOVAs on a-priori selected time windows and electrodes, and mass univariate statistics (Groppe, Urbach, & Kutas, 2011) on all electrodes and timepoints.

For ANOVA analyses we selected two time windows and four group of electrodes to investigate the effects, basing our choice on the literature (Molinaro et al., 2015) and prior to any visual inspection of ERP waveforms. We focused on the 350-450 ms windows to investigate the effect of LAN and on the 700-1000 time window to investigate the effect of Late positivities and P600.

To investigate topographical effects, we focused on 12 electrodes grouped in 4 Region of interests (ROI): a left anterior (F3, FC5, FC1) a right anterior (F4, FC6, FC2), a left posterior (CP1, CP5, P3) and right posterior (CP2, CP6, P4). Values for each ROI were calculated as mean amplitude of the electrodes included in the ROI. These ROIs were associated to two variables, *laterality* and *caudality*.

The repeated ANOVAs (separated for the two levels of *contrast* on denoted numerosity and denote objects) condition included four within variables with a $3 \times 2 \times 2 \times 2$ design: *Semantic-F Number* with three levels (one + noun.SG vs. some + noun.PL vs. some^o+ noun.SG), *Congruence* with two

1 levels (True, False), *caudality* with two levels (anterior, posterior) and *laterality* with two levels
2 (left, right).

3 When more than two levels of a repeated measure variable were involved, a preliminary Mauchly
4 test for sphericity was performed. If sphericity assumption was not met, Greenhouse-Geisser
5 correction was applied. Effect size for ANOVA effects was calculated as global eta squared (η_G^2) a
6 more accurate estimate of effect size than traditional η_p^2 in the case of repeated measure design
7 (Bakeman, 2005). Post-hoc contrasts were performed by means of paired t-tests, corrected for
8 multiple comparisons with no Discovery Rate (FDR) correction method (Benjamini & Hochberg,
9 1995). All post-hocs performed are reported in the Supplemental Data.

10 We also analysed the data also using a mass univariate approach (Groppe, Urbach, & Kutas, 2011).
11 In this analysis we performed a series of separate t-tests for each time point and each electrode
12 starting from 0 to 1000 ms (in the ERPs time-locked to the noun), separately for each type of
13 contrast (on depicted numerosity or on depicted object) and separately for each *Semantic F-Number*
14 (*one+noun.SG* vs. *some+noun.PL* vs. *some^o+ noun.SG*), we investigated the effect of *Congruence*
15 (congruent trial vs. incongruent trial). Within each contrast we corrected for inflated type-1 error
16 associated to the high number of comparisons using FDR correction for time points and electrodes.
17 To be more stringent in our analysis, we also excluded all those effects that lasted less than 50 ms
18 (probably ascribable to noise, rather than to real effects).

19 The results on the first words (i.e., the quantifiers) were difficult to be compared, as the quantifiers
20 showed intrinsic differences, in length and frequency, that are relevant confounds to the effects of
21 interest. For the sake of transparency and completeness, we used a similar mass univariate approach
22 to analyse the results on the first word, but in a more exploratory fashion (as we did not have
23 specific hypotheses). Detailed results for the first word are reported in the Supplemental Data.

24

25 **3. Results**

26

27 **3.1. Behavioural analysis**

28

29 The performance in the task was almost at ceiling in almost all of the subjects. The mean percentage
30 of errors was 0.8% on the total of 360 stimuli (mean number of errors = 2.96, SD = 3.513, range =
31 0-13). As the performance was almost at ceiling, data on accuracy were not further analysed. As
32 there was no time pressure to give the response, reaction times were not analysed.

33 As all the participants performed the task with high accuracy, this ensured they understood the task
34 and paid attention to the stimuli that were included in the analysis.

35

36 **3.2. EEG analysis**

37 ERPs grandaverages time locked to the content word for selected electrodes and topographic plots
38 of the effect in the early time window (350-450), are reported in Figure 2 and 3. Further figures on
39 all electrodes are reported in the Supplemental Data.

40

41 In the ANOVA analysis only main effects and interaction involving the experimental variables of
42 interest (*Numerosity* and *Congruence*) are reported. Following standard recommendation of
43 reporting statistic results, only higher order significant results are discussed. Full results for
44 ANOVA, as well as details on all post-hocs are reported in the Supplemental Data.

45

3.3. ANOVA analysis

3.3.1. Contrast on depicted numerosity, early time window (350-450)

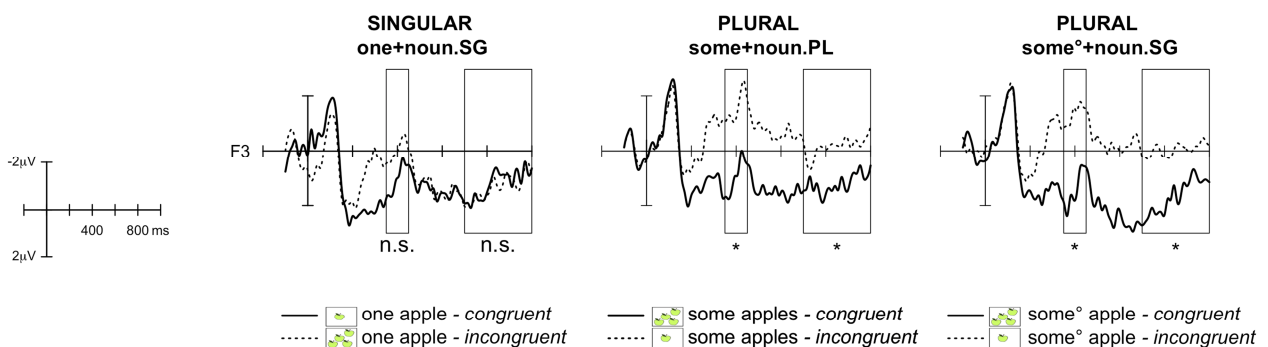
In this analysis we found a significant interaction of *Semantic F-Number* \times *congruence* [$F(2,50) = 5.02$, $p = 0.01$, $\eta_G^2 = 0.03$]. Post-hoc contrasts related to this interactions showing that the two conditions linked to a semantic interpretation of plurality (*some^o+noun.SG* and *some+noun.PL*) had more negative values with the incongruent picture (i.e., a picture depicting one item) as compared to congruent picture (i.e. picture depicting four items) [corrected $ps < 0.05$]. No significant difference was evidenced when the morphological numerosity was singular (i.e. in the conditions involving *one+noun.SG*), regardless the depicted numerosity in the preceding picture (i.e. regardless of the congruence) [$p = 0.24$]. The values for the singular form were similar to the congruent values in the plural form [$ps > 0.05$].

The interaction *Semantic F-Number* \times *laterality* was also significant [$F(2,50) = 3.83$, $p = 0.03^*$], post-hocs showed that in general values were more negative in the left hemisphere than in the right hemisphere. Both in the left and in the right hemispheres, *some+noun.PL* condition has more negative values than *some^o+noun.SG*, which in turn more negative values than *one+noun.SG* [all $ps < 0.05$]. However, this difference was less pronounced for the *one+noun.SG* [$p = 0.047$], as compared to the plural [$ps < 0.01$].

3.3.2. Contrast on depicted numerosity, late time window (700-1000)

This analysis evidenced a significant effect interaction *Semantic F-Number* \times *congruence* [$F(2,50) = 7.31$, $p < 0.001$, $\eta_G^2 = 0.04$]. Post-hocs showed that *some^o+noun.SG* and *some+noun.PL* had less positive values when preceded by the incongruent picture (i.e. a picture depicting one item) as compared to the congruent picture (i.e. a picture depicting four items) [corrected $ps < 0.05$]. When the semantic feature linked to the Number morpheme was interpretable as singular (i.e. conditions involving *one+noun.SG*), no significant differences related to the congruence of the preceding figure [$p = 0.77$] were observed.

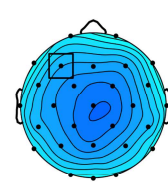
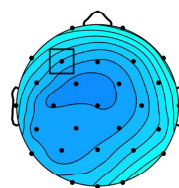
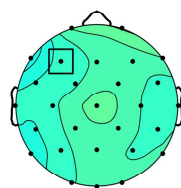
Contrast on Depicted Numerosity



Topoplots

incongruent
minus
congruent

(350 - 450 ms)



-7 μ V +7 μ V

1 **Figure 2. ERP waveforms and main results for the contrast on depicted numerosity.** The figure
 2 shows the ERP waveforms on a representative electrode (F3) and the main results for the ANOVA analysis
 3 for the contrast on depicted numerosity. The upper panels show the waveforms for the three different
 4 quantifier (one+noun.SG, some+noun.PL, and some^o+noun.SG). The square indicates the time windows
 5 used in the analysis and the asterisks indicate that the post-hoc comparing the effects in the time windows
 6 was significant. The bottom row displays topographic plots of the mean effect in the 350-450 ms time
 7 window, used to investigate early components. The small square indicates the electrode represented in the
 8 upper panels.

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12 3.3.3. Contrast on depicted object, early time window (350-450)

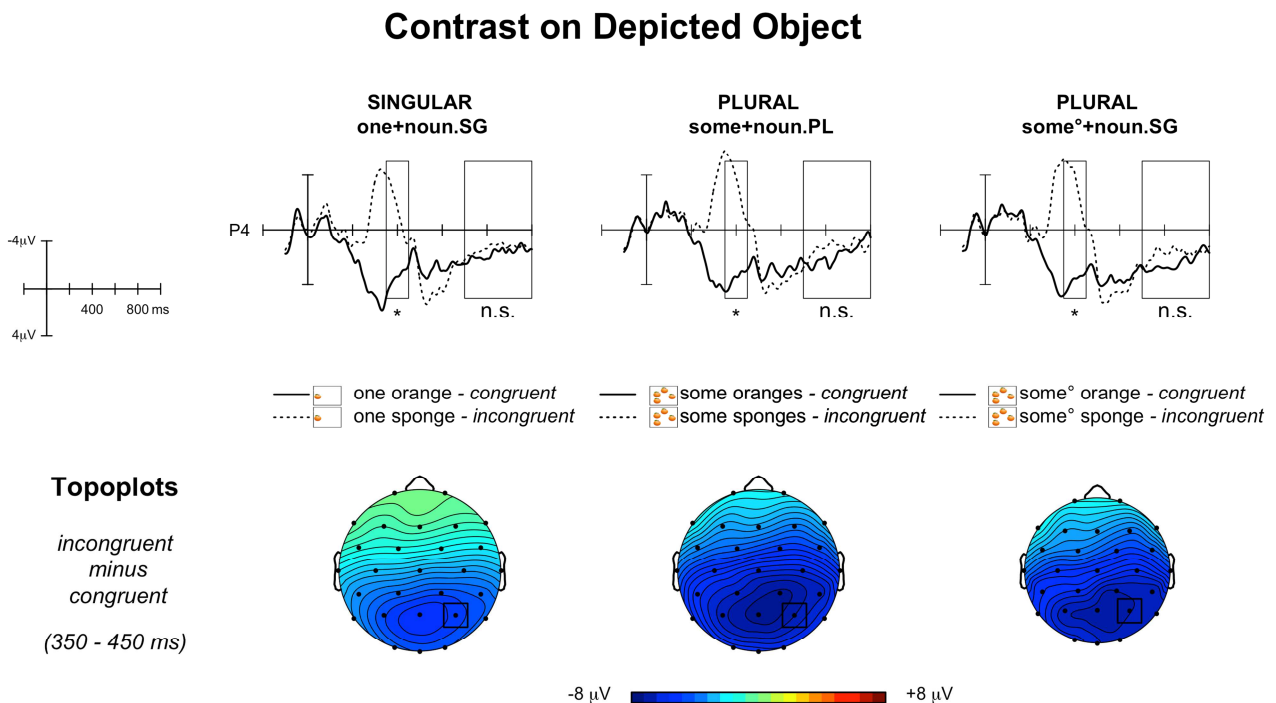
13 In this analysis we found a significant effect of *Semantic F-Number* \times *congruence* [$F(2,50) = 8.04$,
 14 $p < 0.001$, $\eta_G^2 = 0.05$]. Post-hocs of this interaction showed that when the depicted object was
 15 incongruent all *Semantic F-Number* showed more negative values as compared to congruent
 16 depicted objects [$ps < 0.05$]. Moreover, in the case of an incongruent object the semantic feature of
 17 the morphological Number in trials involving *one+noun.SG* had less negative values as compared
 18 to *some^o+noun.SG* and *some+noun.PL* [$ps < 0.05$], which did not differ one from the other [$p =$
 19 0.86].

20

21 3.3.4. Contrast on depicted object, late time window (700-1000)

22 In this time window no significant effect involving the experimental variable was found.

23



24

25 **Figure 3. ERP waveforms and main results for the contrast on depicted object.** The figure shows
 26 the ERP waveforms on a representative electrode (P4) and the main results for the ANOVA analysis for the
 27 contrast on depicted numerosity. The upper panels show the waveforms for the three different quantifier
 28 (one+noun.SG, some+noun.PL, and some^o+noun.SG). The square indicates the time windows used in the
 29 analysis and the asterisks indicate that the post-hoc comparing the effects in the time windows was

1 significant. The bottom row displays topographic plots of the mean effect in the 350-450 ms time window,
2 used to investigate early components. The small square indicates the electrode represented in the upper
3 panels.
4

ACCEPTED MANUSCRIPT

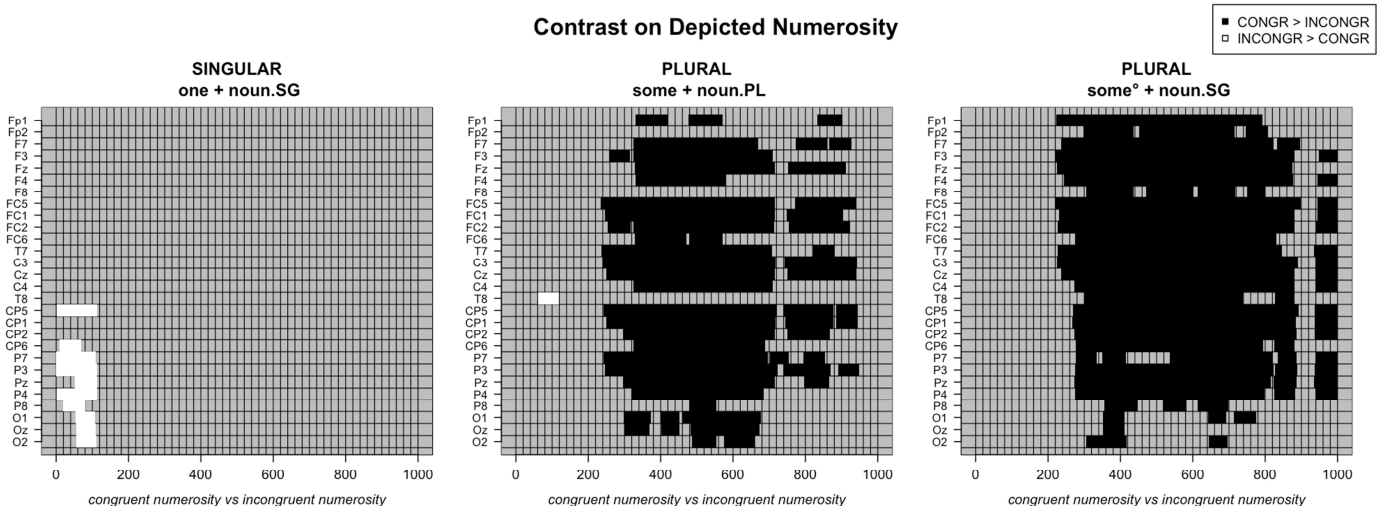
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3.4. Mass Univariate Analysis

3.4.1. Morphological contrasts

Results of Mass univariate analysis are reported as raster plots in Figure 4 (for the contrast on depicted numerosity) and Figure 5 (for contrasts on depicted object). ERP waveforms for all electrodes and mass univariate results are also reported in the Supplemental Data.

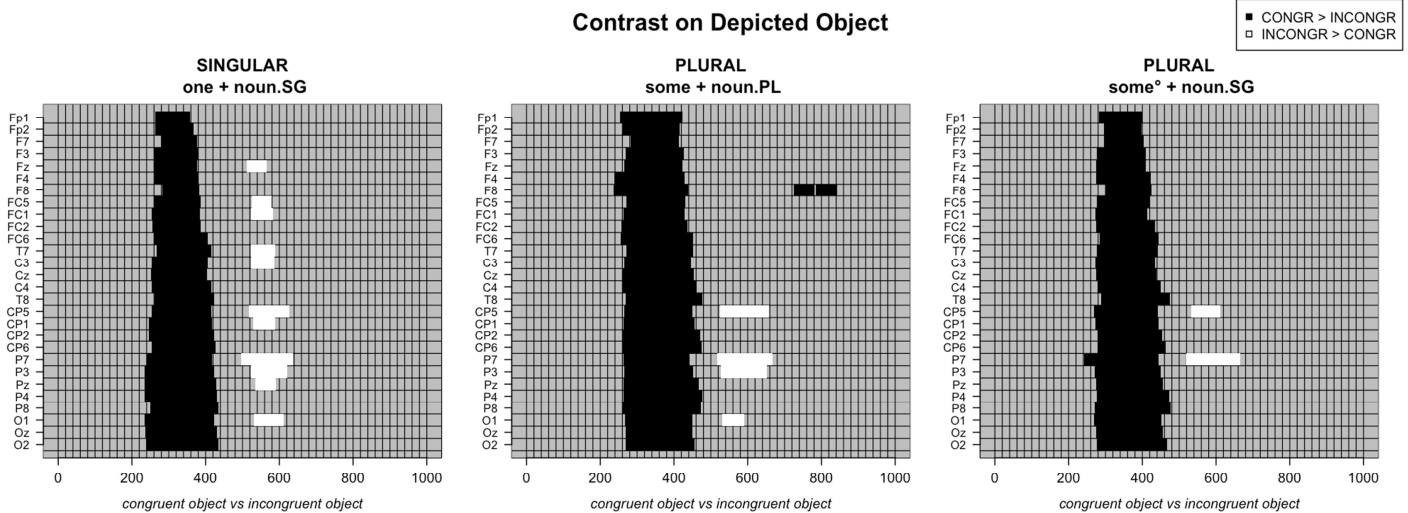
In the contrast on depicted numerosity, the conditions in which the semantic feature of the morphological Number was interpretable as plural (*some^o+noun.SG* and *some+noun.PL*) were characterised by significantly more negative amplitude in the incongruent condition (i.e. the figure with just one item) as compared to the congruent condition (i.e. the figure with four items). The effect was present in the timepoints associated with the early time window (350-450 ms) and in most electrodes was significant also in later timepoints. As for *one+noun.SG*, some significant effects were found, with more positive values for incongruent conditions as compared to the congruent ones in very early time windows (around 0-100 ms after the noun), in centroparietal electrodes. Results are reported in Figure 4.



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Figure 4. Results of Mass Univariate Statistics of Contrast on Depicted Numerosity. The figure shows, in the form of raster plots, the results of mass univariate statistics. In each raster, in the y-axis, each row represents one electrode and the x-axis represents the time. Each cell represents an interval of 10 ms. Grey rectangles denote intervals with no significant effect. Black or white rectangles denote significant effects. In particular, black rectangles indicate that incongruent had more negative values than congruent, while white rectangles indicate that incongruent had more positive values than congruent. Significant effects were calculated from paired t-tests, with p-values corrected with FDR method.

1 In the contrasts on the depicted object, the results showed a significant difference around 250-400
 2 post stimulus, with more negative values for the incongruent conditions as compared to the
 3 congruent ones, especially in posterior electrodes. This difference was qualitatively similar in the
 4 three quantifier types, *one+noun.SG*, *some+noun.PL* and *some^o+noun.SG*. The mass univariate
 5 analysis highlighted another later effect, at around 500-600 ms (comparable across the three
 6 quantifier types) with more positive values for incongruent as compared to congruent trials. This
 7 last effect was found mostly in left lateralized electrodes. Results are reported in Figure 5.



8
 9

10 **Figure 5. Results of Mass Univariate Statistics of Contrast on Depicted Object.** The figure shows, in the
 11 form of raster plots, the results of mass univariate statistics. In each raster, in the y axis, each row represents
 12 one electrode and the x axis represents the time. Each cell represents an interval of 10 ms. Grey rectangles
 13 denote intervals with no significant effect. Black or white rectangles denote significant effects. In particular,
 14 black rectangles indicate that incongruent had more negative values than congruent, while white rectangles
 15 indicate that incongruent had more positive values than congruent. Significant effects were calculated from
 16 paired t-tests, with p-values corrected with FDR method.

17

18

19 4. Discussion

20

21 4.1 Morphological Number incongruence elicits LAN-like effects

22 Both ANOVA and mass univariate statistics converged in highlighting differences on the online
 23 processing of the experimental stimuli (i.e. *one+noun.SG*, *some+noun.PL*, and *some^o+noun.SG*).

24 As a first main result, the congruence between the number of objects in the picture and the semantic
 25 feature linked to the morphological Number of the following phrase modulated the amplitude of the
 26 ERPs in an early time window (350-450 ms), with more negative values in incongruent trials than
 27 in the congruent ones. This early component showed a topography compatible to that of a LAN in
 28 both plural conditions, although, according to both topographic representations and MASS
 29 univariate result it was more left lateralized for *some+noun.PL* and more central for
 30 *some^o+noun.SG*. Differently from the typical LAN that is observed in studies with morpho-
 31 syntactic agreement violations, this component had a longer duration and entailed also the second
 32 analysed window (700-1000 ms), that was designed to capture the P600 (Molinaro et al., 2015).
 33 Probably, this long lasting negativity and the absence of a P600 effect are a consequence of the

1 peculiarity of this task that did not employ any grammatical violation, but a mismatch between the
2 referential numerosity and the morphological Number of the following phrase, and thus did not
3 require any repair or re-analysis processes (DeLong, Quante, & Kutas, 2014, Friederici, 2004).
4 Importantly, a difference between congruent and incongruent trials in this LAN-like component was
5 not found in the case of *one+noun.SG*.

6 In the condition involving contrasts on the depicted object, a negative effect in similar time window
7 was reported for incongruent trials (e.g. a picture of four oranges followed by the phrase *alcuni*
8 *martelli* ‘some hammers’) as compared to the congruent ones (e.g. a picture of four oranges
9 followed by the phrase *alcune arance* ‘some oranges’). However, such negativity had a
10 qualitatively different topography than the one observed in the condition involving contrasts on the
11 depicted numerosity, being more posteriorly localized and thus better interpretable as an N400-like
12 effect. Moreover, this effect was significant for all the phrases, independently from the
13 morphological Number value of the nouns and the denoted numerosity (and only with a little
14 difference for *one+noun.SG* condition), whereas the numerosity congruence effect was not
15 observed for nouns inflected in the singular conveying a numerosity of one.

16 The mass univariate analysis confirmed the results of the ANOVA, indicating greater negativity
17 only for incongruent condition in which the morphological Number is linked to a semantic feature
18 of plurality, but also highlighted some additional results. Indeed, we found an increased positivity
19 (left lateralized) after the N400-like effect in the condition involving the contrast on the depicted
20 object. This effect could reflect a re-analysis after the detected incongruence in which there was a
21 highly expected ending. This kind of situation typically elicits a so-called Semantic P600
22 (Bornkessel-Schlesewsky & Schlewsky, 2008). This effect was not found in the ANOVA because
23 of the different time windows that was selected (a-priori) for that analysis.

24 Crucially, the negativity found for the contrast on depicted numerosity cannot be explained by the
25 neural correlates of generic expectations and predictions performed in the task, but rather it may
26 reflect a more genuine effect of incongruence between the semantic feature of the morphological
27 Number and the referential numerosity. This conclusion is supported both by the topography of the
28 effect (similar to LAN) and by the differences in the early components found between the
29 numerosity and the object conditions (the former more similar to a LAN, the latter more similar to
30 an N400). If our interpretation is correct, we succeed in eliciting a LAN-like effect without
31 exploiting a grammatical violation paradigm, but exploiting violations of a morphological Number
32 value in relation to the referential numerosity. It follows that, assuming that the component we
33 elicited is comparable to the LAN found in literature with grammatical violations, the LAN
34 component can be considered not only an index of difficulties in integrating grammatical anomalies
35 linked with the syntactic level such as agreement mismatches, but also reflecting difficulties in
36 integrating mismatches between values of morphological features in phrase context and extra-
37 linguistic referential features such as numerosity. The LAN has been mostly considered as an index
38 of morpho-syntactic expectancy violation in the literature (e.g. Molinaro, Barber, & Carreiras,
39 2011). However, this is not only true if a linguistic word form does not covary with the relevant one
40 as established by the morpho-syntactic rules (e.g. **I ragazzi.PL corre.SG* ‘the boys runs’), but also
41 if a linguistic word form is not strictly related to the pertinent referential information (i.e. the
42 numerosity of the referent in this study).

43
44 Moreover, these results provide further evidence in favour of an independent LAN that can be
45 triggered irrespectively of the P600 (e.g. Molinaro, Barber, Caffarra, & Carreiras, 2015).

1 On the one hand, such findings are consistent with models claiming for an early effect of the
 2 morphological features during language comprehension (e.g. Friederici, 1995; 2002). On the other
 3 hand, our data can support the view that morphological Number processing in phrase context is not
 4 blind to cognitive salient world features such as numerosity. In the literature it has been already
 5 claimed that morpho-syntactic processing can recruit lexical or discourse-level information to
 6 compute formal relationships between words in a sentence (Barber & Carreiras, 2003, 2005;
 7 Deutsch & Bentin, 2001; Mancini, Molinaro, Rizzi, & Carreiras, 2011; Molinaro, Vespignani, et al.,
 8 2011) Here we show that we count whenever we inflect words for morphological Number in phrase
 9 context.

11 4.2 Partial incremental effects of Number morphology

12 In the contrast on depicted numerosity, we found significant effects on ERP time-locked to the
 13 content noun. In our experimental design, the noun occurred after a first word (i.e. a quantifier) that
 14 was sufficient to signal the morpho-syntactic incongruence: if the quantifier was not congruent with
 15 the preceding picture, there was no need to further process the content noun, as the response to be
 16 provided was surely “false”. Nevertheless, in correspondence to the content noun (except for the
 17 cases involving *one+noun.SG*) we did find a negativity associated with an incongruence effect.
 18 This result speaks against full incremental models, that would predict no need to detect
 19 incongruence with the second word (as the incongruence was already detected in the previous
 20 word). A full incremental model would not be able also to explain the difference of incongruence
 21 effect we found across the quantifiers (i.e., no significant effect of incongruence for *one+noun.SG*).
 22 On the other hand, if Number morphology in phrase context was processed in a wait-and-see
 23 fashion, or if Number morphology was automatically accessed, we would have expected a different
 24 effect, with a bigger LAN in the trials involving *some^o+noun.SG* preceded by a figure representing
 25 four items. In fact, in this case, the morphological Number value of singular of the second word
 26 considered alone is inconsistent with the numerosity depicted in the figure, and it is the presence of
 27 the quantifier *qualche* ‘some’, which allows to interpret it as a plural.

28 Differently from the prediction that could have been made from full incremental models or wait-
 29 and-see models, in the present experiment we found the incongruence effect when the phrases
 30 *some^o+noun.SG* were preceded by figures depicting one item: in this case we observed a greater
 31 LAN-like component as compared to the cases in which the phrases *some^o+noun.SG* were preceded
 32 by figures depicting four items. Thus, our results can best fit with models of partial incremental
 33 processing of language, in which gathered evidence is partially integrated with incoming material
 34 (K. a DeLong et al., 2005; Urbach & Kutas, 2010).

35 It could be argued that the incongruence effect on the morphological conditions found in the present
 36 experiment is the spillover effect from the anomaly of the quantifier. This is, at least in part,
 37 necessarily true, as the incongruence is not just between the figure and the single noun, but the
 38 figure and both the quantifier and the noun together, which convey the semantic feature of the
 39 morphological Number. The present experiment alone does not allow to disentangle whether the
 40 effect on the noun is just a spillover on the quantifier or the sum of an effect on the quantifier plus
 41 another effect on the noun. Similar spillover effects, associated with increased negativities, have
 42 been found in different experimental settings (see for example King & Kutas, 1995) and have been
 43 associated to increased working memory load. In the present experiment, however, we have little
 44 reasons to think that the effects are related only to working memory (see 4.4 Limitations).

1

2 **4.3 On the differences in the processing of singular and plural**

3 As pointed out in the review by Molinaro and colleagues (2011; see the introduction), usually in
4 ERP studies dealing with agreement, the morphological Number values of singular and plural are
5 collapsed together in the analyses. Here we contrasted these two Number values and found a
6 difference in the ERP correlates between the processing of nouns inflected in the singular and in the
7 plural. More precisely, an important result in our study concerns the absence of any incongruence
8 effect in the experimental trials involving *one+noun.SG*, i.e. when the nouns were inflected in the
9 singular bearing a numerosity equal to one. Differently, we did find incongruence effects when the
10 nouns were inflected in the plural bearing a numerosity of plurality (*some+noun.PL*). We found
11 incongruence effects even in the case in which the numerosity was not specified at the morpheme
12 level, but -unambiguously- at the phrase level (*some^o+noun.SG*). Hence, whenever a morphological
13 Number value in the phrase context was linked to a numerosity greater than one and was preceded
14 by a picture of one item, it elicited a LAN-like effect. On the contrary, when a morphological
15 Number value was linked to numerosity equal to one and was preceded by a picture of four items,
16 no LAN-like effect was observed.

17 A tentative explanation for such pattern may relay on the fact that plurality -when encoded into
18 Number morphology in the phrase context- has a narrower interpretability than the singular. At a
19 first glance, this can be surprising. And yet, a birds-eye-view of linguistic typology provides a more
20 coherent picture. Besides singular and plural, many human languages can display other dedicated
21 morphological Number values such as general, dual, trial, quadral, paucal, greater paucal, greater
22 plural and collective. Interestingly enough, no language displays a Number system of ten values
23 while most languages have a singular vs. plural system (e.g. Corbett, 2000). As a consequence, the
24 information about numerosity that would be encoded in specific morphological Number values can
25 be encoded into language with different means (e.g. lexically) or can be syncretically conveyed by
26 the available values (Ackerman & Malouf, 2013; Carstairs, 1987; Loporcaro, 2011; Muller, 2007;
27 Pirrelli & Battista, 2000; Stump, 1991; 2006; 2010). From a typological point of view, singular,
28 more than plural, is prone to be the default unmarked morphological Number value and can often
29 syncretically convey other values such as general Number (e.g. an underdetermination of the
30 numerosity) or can even express uncountability in the case of mass expressions, as in Italian (e.g. *il*
31 *mio pappagallo ha mangiato troppa mela* ‘my parrot ate too much apple.SG’; for Italian see, among
32 others, Acquaviva, 2013). Even if we constrained the interpretability of the morphological Number
33 values in our experiment by means of the quantifiers (i.e. ‘one, some, ^osome’), a difference still
34 emerged along the lines shown in typology.

35 An alternative interpretation of the results we found may stem from the observation that a set
36 containing many objects (in our case: four) always contains a set of one object as well, while the
37 other way around is not true; This could explain why we found an early negative effect only when a
38 morphological Number value in the phrase context was linked to a numerosity of plurality and was
39 preceded by a picture of one object: only in this case there is a complete mismatch between the
40 observed numerosity and the expressed morphological Number value. Following this reasoning, one
41 could argue that at least from a semantic point of view it is not singular to be the unmarked value,
42 but plural. Indeed, a line of research has claimed that plural nouns are semantically underspecified
43 for Number since they can quantify over singular objects (Bale, Gagnon, & Khanjian, 2011; Krifka,
44 1989; Sauerland, 2008). For example, a question like “are there any English professors in the
45 room?” can be answered affirmatively even if there is only one English professor in the room.

1 Although interesting, this kind of approach does not seem to fit properly our pattern of results at
 2 least for two reasons. Firstly, if it is true that plural nouns are semantically underspecified for
 3 Number we should *not* have observed a LAN-like effect when *some+noun.PL* (and
 4 *some^o+noun.SG*) phrases were read after the picture of one object. Secondly, as explained in §4.1,
 5 we did not find any significant difference between singular and plural trials in the purely semantic
 6 condition involving contrasts on the depicted object (e.g. a picture of four oranges followed by the
 7 phrase *alcuni martelli* ‘some hammers ’). Taken together, these observations rather support a
 8 morphological explanation for the LAN-like effect we reported, suggesting that plurality at the
 9 phrase level is likely to receive a narrower interpretability than the singular.

10 Whatever the interpretation, the pattern of results we found is hardly reconcilable with a view of
 11 (Number) morphology as a strictly associative function between a form and a meaning. According
 12 to this perspective, in Italian the singular-plural opposition should mostly reflect the contrast of a
 13 referential numerosity of one vs. a referential numerosity different from one. If this was the case,
 14 we should have found a similar incongruence effect in the trials involving plural Number
 15 morphology as well as in the trials involving singular Number morphology. Instead, we found an
 16 incongruence effect only in the trials involving plurality at the phrase level. We propose here that
 17 there would be no actual contrast between a value denoting one and a value denoting numerosity
 18 different from one. Rather, the singular is more likely to be underspecified with respect to plural
 19 and thus this latter is more prone to receive a specific interpretation. This perspective is also
 20 consistent with recent findings on acquisition claiming for a discriminative morphological
 21 processing which should allow to separate systematically informative and predictive cues from less
 22 predictive ones with respect to a context (e.g. Ramscar, Dye, Blevins, & Baayen, 2015; Ramscar &
 23 Port, 2015; see also Rescorla, 1988).

24 **Implications for theories on morphological processing**

25 The majority of studies on morphological processing of written words assumes that complex words
 26 are early decomposed, and that this decomposition depends on the structural properties of the words
 27 (for a review see Amenta & Crepaldi, 2012). However which characteristics drive a morphological
 28 decomposition and what kind of information is accessed during processing is still a matter of debate
 29 (e.g., for a view that does not postulate a stage of morphological decomposition, see Baayen,
 30 Hendrix, & Marelli, 2011). An interesting perspective related to the issue of morphological
 31 processing is that posited by Norris (2006), according to which several effects observable in
 32 psycholinguistic tasks (not necessarily on morphology) can be explained assuming that we behave
 33 as “Bayesian Readers”, making probabilistic choices that highly depend on the task goals. In
 34 particular, the “Bayesian Reader” theory is able to explain parsimoniously several inconsistencies
 35 found in the literature of masked priming and lexical decision (Kinoshita & Norris, 2012). This is of
 36 particular relevance for theories on morphological processing, as the large majority of studies on
 37 this topics comes indeed from experiments employing masked priming and lexical decision
 38 (Amenta & Crepaldi, 2012). Some interesting thoughts on this issue come from the study by Marelli
 39 and colleagues (Marelli, Amenta, Morone, & Crepaldi, 2013), who reports results from two
 40 experiments: using a lexical decision task, the authors were able to replicate the classical effects
 41 found in the literature (i.e., an early effect of morpho-orthographic decomposition based on word
 42 structure); however, the same results were not found ~~when using a reading task where the critical~~
 43 ~~words were embedded in a phrasal context~~ in another experiment, in which eye movements were
 44 recorded and participants were required to perform a comprehension task. Thus, results by Marelli
 45

1 and collaborators suggest the importance of relying on different tasks and settings to address the
2 issues of morphological decomposition.

3 Within this debate, most of the studies focused on derivational morphology or compounding, and
4 relatively few studies investigated the effects inflectional morphology and the difference between
5 singular/plural (but see for example Baayen, Dijkstra, & Schreuder, 1997). In the present paper we
6 showed that, at least, for Number morphology, a phrasal context and a picture-phrase matching task
7 may override the effects of Number value associated with the word taken in isolation: when the
8 number Value of the two-word phrase used in the experiment was plural (even if the inflectional
9 suffix of the word was singular), we found incongruence related ERPs, if the referential picture
10 depicted only one object. Given the nature of the task and contrasts we used, we cannot fully
11 disentangle whether and how this effect is related to a morphological decomposition of the inflected
12 words; however, the topography of the effects (LAN-like) is traditionally associated to morpho-
13 syntactic operations, and the latency of the effects is the same of to found in studies on
14 decomposition in morphologically complex words (Koester, Gunter, & Wagner, 2007; Lavric,
15 Clapp, & Rastle, 2007). Hence, it could be concluded that the operation performed in the current
16 study is associated with some kind of morpho-syntactic processing on the single words. However,
17 given the potential confound of a spillover effect (see § 4.4), further evidence is needed to
18 corroborate this conclusion. Following Marelli et al., 2013, we think that to fully understand how
19 number morphology processing unfolds over time, we need to rely on ~~more~~ diversified tasks,
20 measures, and settings, and not only on reaction times gathered from lexical decision studies. ~~words~~
21 ~~in isolation but also in more ecological phrasal contexts.~~

24 4.4 Limitations

25 An important limitation of the present study concerns the interpretation of the effect of congruence
26 in terms of a LAN. It may be argued that the difference in the congruent or incongruent trials is not
27 necessarily a LAN, but another ERP component with different meaning, interpretation and neural
28 generator.

29 For example, a first alternative explanation is that the effect reflects more positive values for
30 congruent as compared to the incongruent trials; in other words, the difference would reflect a
31 P300-like effect rather than a LAN (Polich, 2007). Another possible explanation is that the
32 negativity is not actually a LAN, but rather a long-lasting negativity that reflects an additional
33 processing possibly related to working memory (King & Kutas, 1995); this may arise in the
34 presence of an incongruent quantifier and may be carried on the following noun as well. A third
35 potential criticism is related to the distribution of the effect of our LAN-like components, that in the
36 case of *one+noun.SG* was bilateral and not left lateralized. This result may suggest that the
37 component we found does not actually resemble a LAN.

38 These explanations are intriguing possibilities that deserve to be further explored. Yet, we believe
39 that even if the effects we found do not reflect a traditional LAN, this does not affect the relevance
40 of the results. In fact, these more general accounts and explanations are hardly reconcilable with the
41 absence of any incongruence effect in the trials involving the Number value of singular
42 (*one+noun.SG*). Indeed, a generic effect of incongruence of working memory would not predict an
43 interaction with a specific Number value in a specific context (which is the main result of the
44 present study). Thus, it is likely that we managed to capture a specific effect of congruence between
45 the depicted referential numerosity and the morphological Number value.

1 As for a long-lasting effect of incongruence on the quantifier, if this was the case, we would expect
2 that the baseline correction should cancel out this difference. As the baseline correction procedure
3 worked almost always we can reasonably conclude that a long-lasting effect cannot be the only
4 explanation for the results we found. Time locking the ERPs to the noun was important to exclude
5 any possible confound on more superficial characteristics of the quantifiers, which are intrinsically
6 different (as for length or frequency) and to rule out several possible confounding explanations.
7 Importantly, even if the effect of the noun is related to a spillover from the quantifier rather than a
8 pure effect on the noun, this does not affect the interpretation of the results, which is indeed related
9 not to the single noun, but to the phrase, composed by the quantifier and the noun.

10 Finally, although LAN is (by definition) left lateralized, several studies shows a bilateral
11 distribution of LAN (e.g., Hagoort, Wassenaar, & Brown, 2003; Yamada & Neville, 2007; Ye, Luo,
12 Friederici, & Zhou, 2006). However, the functional difference between these two different
13 distributions is not known (Hahne & Friederici, 2002; Pakulak & Neville, 2010). As both the
14 traditional LAN and our LAN-like components are just the electrode manifestation of underlying
15 brain activities, a mere comparison in terms of spatial distribution of effects of electrodes is
16 unreliable to infer neural generators (Urbach & Kutas, 2002, 2006). Rather, a more interesting and
17 promising prospective to tackle this issue is to compare the LAN found in traditional morphological
18 studies with the component found in the present experiment by using source reconstruction
19 techniques in order to characterize the neural generators of the observed components. In this way it
20 would be possible to trace back the difference in the brain regions recruited during the processing.

21 It is worth to make some considerations on the early component found in the Mass Univariate
22 Statistics on *one+noun.SG*. In this condition we found an early positivity in some parietal
23 electrodes, with more positive values for incongruent than for congruent condition. This effect was
24 present in a very early time window (starting from 0). Given this early beginning it is likely that this
25 component is a spurious effect related to a former component elicited by the First stimulus (the
26 quantifier, see the Supplemental Data) and that could have affected the baseline correction time-
27 locked to the Second word (the object) in the analyses. Crucially to our aims, this result does not
28 affect the main conclusions of the present paper for two reasons: firstly, these effects were not
29 found in the electrodes in which the LAN was obtained but in other electrodes; secondly, in the
30 analysis on the early time window (350-450 ms) the value for *one+noun.SG* (both congruent and
31 incongruent) was similar to the congruent condition for *some+noun.PL* and *some+noun.SG*. This
32 suggests that for *one+noun.SG* there is actually no modulation for incongruence, a result that would
33 be hardly reconcilable with a potential confound of the baseline correction. Future study varying
34 inter-trial stimulus and with different stimuli (or different languages) are necessary to disentangle
35 the meaning of this effect.

36 In a previous study by our research group (Gastaldon et al., 2016) we examined the RTs in a
37 picture-sentence congruence task similar to the present one. In that task, quantifier and noun were
38 displayed simultaneously and the participants were asked to respond whether picture and phrase
39 were congruent or not as soon as possible. We found slower RTs for *some^o+noun.SG* as compared
40 to all other conditions, irrespective of congruence. This is in contrast with the results of the present
41 study in which it was rather *one+noun.SG* that showed a different processing as compared to the
42 other conditions. There are several reasons that could explain these different patterns. A first one is
43 purely methodological: as in the Gastaldon et al. (2016) task the dependent variable were the RTs to
44 a decision, it is possible that we found more strategic aspects that were associated with the response
45 strategy rather than a genuine linguistic process. The fact that we did not find an interaction with

1 congruence could indeed support this conclusion. Additionally, in the behavioural study as both
2 words were presented simultaneously it was not possible to disentangle the source of the effect (the
3 quantifier, the noun, or both). The second one is related to the different processing opportunities
4 that each task entailed: if the whole sequence is available, this could favour a holistic processing of
5 both words, that was not possible in the current ERP study (in which words were presented in a
6 word-by-word fashion). We argue that only an eye-tracking study could disentangle this issue,
7 investigating the effect of landing position (that could allow a processing only of the quantifier or of
8 both the quantifier and the noun) on the reading times of the quantifier-noun phrase.

11 5. Conclusions

12 In this study we investigated the ERP correlates of incongruence between the depicted numerosity
13 and phrases. In particular, we focused on the difference between singular and plural. We showed
14 that numerical representation is to some extent accessed during Number morphological processing
15 since incongruence between the referential numerosity and the semantic feature linked to the
16 morphological Number value elicited a negativity that we interpreted as a LAN-like effect, even in
17 the absence of a proper morpho-syntactic violation. This result can further support the view of the
18 LAN component as an index of a genuine morphological processing irrespective the grammaticality
19 of the utterances.

20 We hypothesise that if Number morphology and its processing can reflect cognitive salient
21 information about numerosity, they do so in a non-strictly-associative fashion. In fact, we failed to
22 observe significant incongruence effects in trials involving the morphological Number value of
23 singular. Since a LAN-like effect was found only in trials involving plurality at the phrase level, we
24 suggested that this latter has a narrower interpretability than the singular. Singular is the default
25 unmarked value not only in Italian, but in the great majority of the world languages, it cannot be
26 strictly associated to a numerosity equal to one irrespectively of the communicative context, and
27 can express unspecified numerosity as well as uncountability.

28 In conclusion, this paper raises several questions that could stimulate further research in the field.
29 Can the pattern of results be replicated in languages with the same Number system of Italian, i.e.
30 singular vs. plural? Can this pattern be differently modulated in languages with other Number
31 systems such as singular-plural-dual or general-singular-plural? If Number morphology reflects
32 salient core knowledge information, what about other morphological features such as Gender? More
33 generally, does inflectional morphology reflect salient information represented by the core
34 knowledge systems? Mostly, these questions will benefit from further investigation on typologically
35 different languages.

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Authors contribution

Study Design: CZ, FF, GA. Pilot studies and stimuli selection: GA, SG, SB. Data collection and EEG pre-processing: GA, SG, SB. Statistical analysis: GA. Manuscript Preparation: GA, CZ, FF. Scientific Supervision on all steps: FP, CS. All authors provided feedback on the draft and approved the final version of the manuscript.

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