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Grammatical number processing: Psycholinguistic evidence from Polish

PhD thesis written

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Wrocław 2020

Uniwersytet Wrocławski

Wydział Filologiczny

Instytut Filologii Angielskiej

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Przetwarzanie liczby gramatycznej: Dowody psycholingwistyczne z języka polskiego

Rozprawa doktorska

napisana pod kierunkiem

dr. hab. Joanny Błaszczak, prof. UWr

Wrocław 2020

Acknowledgments

I would like to thank my supervisor, Professor Joanna Błaszczak, for all the advice, comments and suggestions and most of all for the incredible patience with which she handled all my not-always-brilliant ideas over the years. My thanks go also to Veranika for taking the time to read too many different versions of this work and providing the right type of support when it was most needed.

I am grateful to everyone who participated in the experiments.

This thesis was written as part of the project titled *Psycholinguistic investigations into number and quantification in natural language* funded by The National Science Centre within the programme OPUS 5 (DEC-2013/09/B/HS2/02763). Modified fragments of the thesis have been used in Gulgowski & Błaszczak (2018) and Gulgowski (2019).

Table of contents

List of tables

List of figures

Abbreviations

3	3rd person
ACC	accusative
DU	dual
ERP	event-related potential
GEN	genitive
INS	instrumental
IPFV	imperfective
NEG	negation
NOM	nominative
PL	plural
PST	past
REFL	reflexive
SCE	size congruity effect
SG	singular
SNARC	spatial-numerical association of response codes

CHAPTER I

OVERVIEW

1 Statement of the problem

Every day we encounter problems that require the ability to use numbers. How many guests attended the party? How many cookies are left in the jar? With so much significance in everyday life, it is not surprising that number found its place in natural languages. There are number words that identify specific numerosities (e.g., *three, fifteen*) as well as various quantifiers expressing amounts or relations between sets (e.g., *some, much, a lot of*). Number information can be expressed through lexical differences between words like *army* and *soldier*. Crucially, in many languages number has the status of a grammatical category, as reflected, for instance, in the regular contrasts found for English nouns, like *dog* vs. *dogs* or *tree* vs. *trees*. Grammatical number has long attracted the attention of linguists, logicians and philosophers looking for ways to capture the meaning distinctions associated with this category or to provide a typological description of possible number values and the various linguistic devices used to express them in languages across the world.

From a psycholinguistic perspective, the processing of grammatical number presents a wealth of research opportunities. In languages like English or Polish, it is an obligatory property of nouns, forcing the speakers to take this feature into account in both production and comprehension. The manner and timing of its acquisition has helped to inform developmental theories (Clark & Nikitina, 2009; Kouider et al., 2006; Lukyanenko & Fisher, 2014; Tieu et al., 2014). Investigating how number features on nouns and pronouns influence the form of other elements in the sentence is an important part of agreement research (Bock & Miller, 1991; Eberhard, 1997; Nevins et al., 2007). Studies of number markers have been useful in understanding how language users handle the morphological structure of words (Baayen, Burani, et al., 1997; Baayen, Dijkstra, et al., 1997; New et al., 2004; Van Der Molen & Morton, 1979). Researchers interested in the organization of conceptual knowledge analyze how comprehenders use grammatical number information to create mental quantity representations, potentially including details like the spatial configuration of the set elements (Patson et al., 2014; Patson, 2016b).

Despite an important role of grammatical number in multiple fields of psycholinguistic research, still not much is known about some aspects of number processing. The mechanism through which number information is extracted from individual words during language comprehension, converted into numerical concepts and then combined with the rest of the expression is still largely unclear. This is especially true for cases where the grammatical number and the intended numerical interpretation are incongruent (good examples are collective words, like *group*, and *pluralia tantum* words, like *glasses* or *jeans*). Language comprehenders also face challenges when integrating grammatical number with the wider context, which may contain other quantity-related elements (for instance, the singular noun *book* in the phrase *every book* can refer to multiple books). The exact mechanisms of number extraction and interpretation, and the factors that could affect them, are seldom addressed directly in experimental research on language comprehension.

The aim of the current thesis is to shed more light on those issues by presenting the results of six psycholinguistic experiments conducted with native speakers of Polish. They were designed to make use of the specific properties of the Polish language in order to investigate how lexical, morphological and compositional properties of linguistic expressions affect the processing of grammatical number information. The experiments used techniques derived from research on numerical cognition, that is the general ability to process symbolic and non-symbolic numerosity (Feigenson et al., 2004). More specifically, the experiments used the numerical Stroop interference (Naparstek & Henik, 2010), the SNARC effect (Dehaene et al., 1993) and the numerical size congruity effect (Cohen Kadosh et al., 2007). Phenomena related to general numerical cognition are promising, yet still underused, tools for studying number in language. The few studies that applied such techniques to investigating grammatical number processing before provided evidence that encountering words bearing a number value automatically activates a concept of quantity, which may interfere with responses in number-related tasks (Berent et al., 2005; Patson & Warren, 2010; Röttger & Domahs, 2015). In addition to its primary empirical goals, the present work offers a methodological contribution by testing further the validity of applying those techniques to the field of grammatical number research.

The rest of this chapter begins with a discussion of the status of number as a grammatical category in natural languages and a brief look at numerical cognition outside language. An overview of previous studies exploring the processing of grammatical number will be provided later in the chapter. This will be followed by a discussion of specific research problems addressed in the present thesis and the chosen methodology. The chapter ends with a presentation of the thesis outline.

2 Grammatical number in natural languages

Due to a considerable variety among world languages, providing a precise definition of grammatical number is a tricky task. It is mostly a nominal category relevant for the form and interpretation of nouns and pronouns.[1] Semantically, it is quantity-related, allowing the speakers to communicate how many things they have in mind.[2] This is accomplished either by

[1] Verbal number (also known as pluractionality) is typically understood as reference to multiple events through the means of verbal markers. For a discussion of verbal number, see Durie (1986), Corbett (2000) or Hofherr (2010).

[2] Number forms can also acquire special secondary uses. For example, plural number can be used to provide additional emphasis, express the abundance of something or to metonymically refer to the inhabitants of the place named by a plural noun (Corbett, 2000, Ch. 7).

modifying the form of a word or by introducing a separate number element. Grammatical number tends to be inflectional rather than derivational, i.e., it adds extra information to the meaning of a word without altering its core semantic features or changing its syntactic category.[3] In many languages, number enters into morphosyntactic relations between sentence constituents in the form of agreement.

2.1 Possible number values[4]

Languages differ with respect to how many number values they distinguish. In some languages, like Chinese, number as a grammatical category simply does not exist, although numerical distinctions can still be expressed periphrastically. For some language communities number seems to be of relatively low importance for cultural reasons, which is reflected in a bare-bones number system. Pirahã, an Amazonian language from the Mura family with no grammatical number and a very limited set of numerals and quantifiers, is a widely discussed example (Frank et al., 2008; Gordon, 2004). The simplest grammatical number system, familiar to speakers of most European languages, involves a two-way opposition between ***singular*** and ***plural*** forms. The former refer to just one entity whereas the latter are used to talk about a set of two or more things. In English and Polish virtually every noun is either singular or plural, but not every language with number distinctions is so strict. In some languages, ***general number*** forms (also known as "transnumerals") allow the speakers to avoid providing number information. For example, in the Fula language (from the Niger-Congo family), bare nouns (e.g., *toti* 'toad(s)') are neutral as to the number of referents in question, while marked forms convey specific number meaning (e.g., *totii-ru* 'toad', *totii-ji* 'toads'). The basic singular-plural system can be extended by additional number values encoding specific numerosities. For example, speakers of Upper Sorbian (Slavic) use ***dual*** forms to refer to exactly two objects and Larike (Austronesian) speakers use ***trial*** number to talk about exactly three things. The

[3] This is not uncontroversial. For instance, Booij (1993) discusses examples of plural nouns participating in word-forming processes (compounding and derivation), which does not fit the traditional understanding of how inflected forms should behave.

[4] The following overview is based mostly on Greville Corbett's comprehensive monograph on grammatical number (Corbett, 2000).

meaning of “three entities” seems to be the highest exact numerosity easily encoded through grammatical number. Although some languages have been claimed to possess a ***quadral*** number, caution should be advised when approaching such claims, since, after a more careful analysis, the purported quadrals usually turn out to refer to quantities other than strictly four (Corbett, 2000, p. 30). Candidates for possible quadral include two Austronesian languages: Sursurunga (Hutchisson, 1986) and Marshallese (Bender, 1978). Regardless of the status of quadral, it seems impossible to use grammatical number to point to exactly five, six, etc. objects, but some natural languages allow their users to talk about a small group of things with imprecise numerical boundaries, often determined by context. This is accomplished through the use of number forms known as ***paucals***. This number value is present in languages like Bayso (Afro-Asiatic), where it refers to a group of up to around six individuals. In Lihir (Austronesian), paucal exists alongside singular, dual, trial and plural, resulting in a five-way system, the maximum number of distinctions found in any single natural language according to Corbett (2000, p. 25). Finally, linguists distinguish systems with so called ***greater numbers***, where a language might possess one form with a standard plural meaning and a greater plural used to emphasize that the quantity under discussion is very large or excessive. Examples include the Niger-Congo languages of Banyun and Fula.

2.2 Possible forms of number expression[5]

Languages can choose different means through which the available grammatical number values are expressed. The most commonly found device is ***affixation***. According to the data available at the World Atlas of Language Structure website (Dryer & Haspelmath, 2013), prefixes and suffixes are markers of plurality in 631 languages out of a sample of 1066 languages. Plural affixation is common in Indo-European languages. Another relatively common way of expressing number is by ***changing the stem*** of the word. In Maricopa (a North American language from the Hokan family), *humar* ‘child’ can be pluralized to *humaar*

[5] Unless otherwise indicated, information in this section has been taken from the World Atlas of Language Structure (WALS) available online under wals.info (Dryer & Haspelmath, 2013), in particular from the section on the coding of nominal plurality by Matthew Dryer (Dryer, 2013).

‘children’. In some languages number oppositions are marked through ***tonal differences***. In Ngiti (from the Central Sudanic family, spoken in the Democratic Republic of Congo) *kamà* means ‘chief’ while *kámá* stands for ‘chiefs’. ***Reduplication*** constitutes an interesting case, as it can arguably be seen as an example of iconicity in grammar (the multiplicity of referents reflected in a phonological repetition). Reduplication can be complete or partial. In Indonesian, *rumah* ‘house’ contrasts with *rumah-rumah* ‘houses’, while in Pipil (Uto-Aztecan) *rayis* ‘root’ pluralizes to *rah-rayis* ‘roots’. Another form of number expression are ***clitics***. Being more independent than affixes in terms of their morphosyntactic status, number clitics attach to a whole noun phrase or its fragment, instead of the head noun itself. This is the case, for example, in Sinaugoro (Austronesian), where constructions like *belema bara=ria* ‘python big=PL’ are used. Some languages offer ***independent function words*** whose main purpose is to mark grammatical number. In Tagalog (Austronesian), the particle *mga* contributes a plural meaning (Schachter & Otanes, 1983), like in the example below.

(1) *Silya ang mga ito*
chair the PL this
‘These are chairs.’

It is important to note that the typical situation is for a language to make use of two or more types of number expressions, with one (primary) typically being significantly more frequent than the rest. For example, although the main way of expressing number in English is through suffixation, some nouns mark number contrasts by a stem change, as in *goose* vs. *geese*. If no expression is clearly dominant, the language is described as having a ***mixed system***. An example of this situation is Misantla Totonac (Totonacan family from present day Mexico), which marks plurality through both prefixes and suffixes (e.g., *lii-šaaluh* ‘PL-pot’ vs. *míŋ-kam-án* ‘2.POSS-offspring-PL’).

2.3 Number agreement

As stated above, grammatical number is primarily a nominal category. However, like the categories of gender or person, number enters into the morphosyntactic relations of ***agreement***.

Agreement can be defined as a "systematic covariance between a semantic and formal property of one element and a formal property of another" (Steele, 1978, p. 610, quoted in Häussler, 2009, p. 28). In accordance with this definition, the grammatical number of a noun or a pronoun can covary with the form of other elements in the sentence (sometimes separated by several intervening words): determiners (e.g., ***this*** <u>book</u>/***these*** <u>books</u>), verbs (e.g., *The new* <u>*book*</u> *of this author* ***sells*** *well*/*The new* <u>*books*</u> *of this author* ***sell*** *well*) or adjectives (e.g., Polish adjectives in noun phrases: ***ciekawa*** <u>*książka*</u> 'interesting.SG book'/***ciekawe*** <u>*książki*</u> 'interesting.PL books'). Those additional manifestations of number establish syntactic relations between words.

2.4 Grammatical number in Polish

The empirical work forming the basis of this thesis consists of experiments conducted with native speakers of Polish and using Polish stimuli. It should, therefore, be helpful to present at this point a brief description of grammatical number in Polish. In terms of number values, Polish possesses the most basic number system with the binary singular vs. plural contrast.[6] The forms of number expression, on the other hand, are quite complex. Number is fused with case and expressed through a system of nominal suffixes. The combined effect of two numbers, seven cases, occasional stem mutations, frequent syncretisms and several declensional paradigms (based on gender, animacy and morphophonology) makes for a dazzling variety of case/number endings.

Cross-linguistically, the typical situation is for the singular forms to be morphologically unmarked, while plural forms receive a special marking (Greenberg, 1963, Universal 35). One of the peculiarities of the Polish system is that singular nouns can be marked as well as unmarked. The presence or absence of an overt singular suffix for nominative singulars (the dictionary form) depends primarily on the noun's gender value (Nagórko, 2007, p. 143; Swan, 2002, p. 66; Wiese, 2011, p. 117). Unmarked nominative singular forms are predominant for masculine nouns (e.g., *wilk* 'wolf'), with very few exceptions (e.g., a handful of masculines

[6] There are fossilized forms of past dual number, particularly for nouns referring to natural pairs, which exist alongside ordinary plural forms but are no longer interpreted as dual, e.g., *rękoma* 'hand.INS.PL/DU' vs. *rękami* 'hand.INS.PL' (Nagórko, 2007, p. 111).

inflectionally resembling feminines, like *poet-a* 'poet-NOM.SG', or neuters, like *dziadzi-o* 'grandpa-NOM.SG'). In contrast, the majority of feminine nouns have an overt nominative singular suffix (e.g., *żyraf-a* 'giraffe-NOM.SG'), with the exception of those whose stem ends in a functionally soft consonant, like *wieś* 'village' or *mysz* 'mouse'. All neuter nouns possess an overt singular nominative marking (e.g., *słońc-e* 'sun-NOM.SG').

Table 1: The endings of Polish masculine, neuter and feminine nouns in the singular (adapted from Wiese, 2011, Table 3 and Table 4).[7]

Declensional Paradigm		Nom.	Voc.	Acc.	Loc.	Dat.	Gen.	Ins.
Masculine 1	*student* 'student'	-	*'-e*	*-a*	*'-e*	*-owi*	*-a*	*-em*
Masculine 2	*cukier* 'sugar'	-	*'-e*	-	*'-e*	*-owi*	*-u*	*-em*
Masculine 3	*biolog* 'biologist'	-	*-u*	*-a*	*-u*	*-owi*	*-a*	*'-em*
Masculine 4	*bank* 'bank'	-	*-u*	-	*-u*	*-owi*	*-u*	*'-em*
Masculine 5*	*poeta* 'poet'	*-a*	*-o*	*-ę*	*'-e*	*'-e*	*-i*	*-ą*
Neuter 1	*biuro* 'office'	*-o*	*-o*	*-o*	*'-e*	*-u*	*-a*	*-em*
Neuter 2	*tango* 'tango'	*-o*	*-o*	*-o*	*-u*	*-u*	*-a*	*'-em*
Neuter 3	*pole* 'field'	*-e*	*-e*	*-e*	*-u*	*-u*	*-a*	*-em*
Feminine 1	*lampa* 'lamp'	*-a*	*-o*	*-ę*	*'-e*	*'-e*	*-i*	*-ą*
Feminine 2	*ziemia* 'earth'	*-a*	*-o*	*-ę*	*-i*	*-i*	*-i*	*-ą*
Feminine 3	*gospodyni* 'hostess'	*-i*	*-i*	*-ę*	*-i*	*-i*	*-i*	*-ą*
Feminine 4	*mysz* 'mouse'	-	*-i*	-	*-i*	*-i*	*-i*	*-ą*

*A minor paradigm.

The richness of inflectional morphology makes Polish a good test case for studying the influence of form on conceptual representations during comprehension.

[7] In the table, I followed closely the transcription conventions of Wiese (2011), including the use of "*-i*" to render the ending represented orthographically either as "*-i*" (e.g., *ziemi*, *gospodyni*) or as "*-y*" (e.g., *poety*, *lampy*, *myszy*).

3 Numerical cognition outside language

Accumulating evidence from psychological sciences points to the existence of a “number instinct” responsible for the ability to recognize the exact number of elements in small sets and the ability to estimate the approximate numerosity of elements in bigger sets (Feigenson, Dehaene, & Spelke, 2004). It bears the characteristic features of an innate pre-linguistic cognitive system. Antell & Keating (1983) demonstrated that newborn infants are already capable of distinguishing the numerosities of small sets (e.g., 2 vs. 3 elements), but not of larger sets (e.g., 4 vs. 6 elements). The ability to distinguish bigger numerosities with a gradually increasing precision develops in the following months (Xu & Arriaga, 2007). Five month old infants, still months from acquiring the first words, are able to perform simple arithmetic operations on small sets as demonstrated by the looking-time procedure with (un)expected outcomes of removing or adding objects to a temporarily obscured visual display (Wynn, 1992).

Language is, therefore, not an essential prerequisite for basic numerical cognition. This suggests a genetically conditioned ability, possibly inherited from more distant evolutionary ancestors. Indeed, unless the same ability evolved independently multiple times, numerical cognition seems to have appeared relatively early in the history of animal life. A numerosity-evaluation capacity has been found, for instance, in rhesus monkeys (Barner et al., 2008), chickens (Rugani et al., 2014), fish (Agrillo et al., 2012), ants (Reznikova & Ryabko, 2011) and bees (Howard et al., 2019). Quantity-measuring systems in different organisms show similar qualities and limitations. One of the characteristic properties of numerical cognition is a distance effect. In number comparison experiments, participants are faster to indicate which of two numbers is bigger when the numerical distance between them is large than when it is small. For instance, it is easier to spot a numerical difference between a group of 7 birds and a group of 25 birds than between 7 birds and 9 birds. A related property, known as Weber’s law, is that the same increase in numerosity is easier to notice for small than for large numbers. For example, adding 4 pebbles to a pile of 10 pebbles produces a more noticeable change than does adding 4 pebbles to 100 pebbles. In other words, the ability to discriminate between two numerosities depends more on their ratio than the absolute difference between them (Göbel et al., 2011; Izard & Dehaene, 2008). The distance effect and Weber's law are robust features of number processing in humans and non-human animals (Cantlon & Brannon, 2007; Gibson & Maurer, 2016; van Opstal & Verguts, 2011), which strengthens the hypothesis of the common origin.

The primary mode in which most animals encounter numerosity is through direct, non-symbolic perception, mostly visual (e.g., the number of apples on a tree) or auditory (e.g., the number of repeating notes in a bird call). For humans, numbers come also in the form of arbitrary number symbols (digits or number words) or through even more abstract means (grammatical number, quantifiers). It is likely that the ability to process number symbols develops in an individual (through language-based education) from the underlying instinctive general numerical cognition (Leibovich & Henik, 2013).

4 Grammatical number processing

As a grammatical category, number has an impact on almost every major part of language representation and processing, from morphology through syntax, lexical and compositional semantics to pragmatic reasoning. The ability to use number forms properly is an important step in the acquisition of a child's native language. For those reasons, grammatical number has been a focus of multiple areas of psycholinguistic research.

4.1 Acquisition

How does grammatical number processing develop during language acquisition in childhood? The ability to apply plural formation rules by English-speaking children was the subject of the classic "wug" study by Berko (1958) in the early days of modern psycholinguistics. Participating children (ranging in age between four and seven years) saw pictures of unknown creatures and heard descriptions referring to the creatures with novel words. The children were encouraged to produce plural forms referring to a group of such things (see Figure 1). The results indicated that children in the studied age group knew the rule for plural formation and were able to apply it to new words, although not all allomorphs of the plural suffix were mastered equally well.[8]

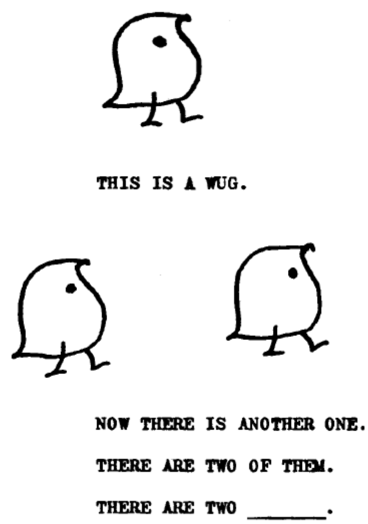

Figure 1: An example of a picture and a corresponding description from an early study on the acquisition of number morphology (Berko, 1958).

Researchers have also been interested in determining the exact age at which children start mapping the singular vs. plural distinction in language onto the conceptual difference between one object and multiple objects. Kuider et al. (2006) conducted a series of experiments with infants of English-speaking parents using the preferential looking technique. Children of two age groups (20 months and 24 months) watched images of novel entities displayed simultaneously on two screens. On each trial, one screen depicted a single novel object and the other screen depicted a set of eight novel objects. An audio recording of a sentence was displayed prompting the child to look at one of the screens. In the first two experiments, the number of referents in the sentence was marked on the verb, quantifier and noun ("Look, there is a blicket" or "Look, there are some blickets"). Twenty-four-month-old infants showed a looking preference for the screen with the array matching the grammatical number. A frame-by-frame analysis revealed that the preference became significant right after the presentation of the verb with the quantifier ("is a" or "are some"). In contrast, 20-month-old infants showed no preference. The time at which English speaking children develop a proper comprehension

[8] Plurals requiring /-s/ and /-z/ were formed accurately, unlike plurals requiring /-əz/.

of grammatical number cues is, therefore, shortly before their second birthday. In the remaining two experiments, the grammatical number marking in the recording was limited exclusively to the noun ("Look at the blicket" or "Look at the blickets"). This time, 24-month-olds failed to show any preference in looking at either the one-object or eight-object array. However, 36-month-olds clearly preferred the array matching the grammatical number of the noun. One possible account given by the authors is that infants learn the proper mapping from verbs or quantifiers at an earlier age (around 24 months) than they learn the proper meaning of nominal number morphology (around 36 months). Another possibility is that the meaning of all number cues is already acquired within the first 24 months, although initially the mapping is weak, requiring the presence of multiple cues in the same sentence. Wood, Kouider & Carrey (2009) obtained similar data using a manual search paradigm. In this study, infants saw an opaque box and heard a sentence about what was inside. The number of objects named in the sentence was either marked on the verb, quantifier and noun or only on the noun. The sentence referred either to one thing ("There is a car in the box", "I see my car in my box") or to multiple things ("There are some cars in the box", "I see my cars in my box"). After hearing the sentence, the child could reach into the box, looking for the items. When number was triple-marked, 24-month-old infants searched longer, if the sentence did not match the contents of the box. In contrast, 20-month-old infants did not change their searching pattern based on the verbal information. When the number was marked on the noun alone, children of neither age group searched longer for the missing objects on incongruent trials.

4.2 Agreement attraction

Number has featured prominently in agreement studies. In agreement research, the processing of grammatical number as a property of nouns and pronouns is studied only indirectly, through the influence it has on other sentence elements. Nevertheless, such investigations reveal something about the role of this category in general language processing. A particularly noteworthy area is agreement attraction. Agreement attraction occurs when the verb disagrees in number with its subject, but language users are still likely to treat the sentence as correct because the verb matches the number value of a different noun in the sentence. In sentence (2), the noun *cabinets* is a potential “number attractor” embedded in a prepositional phrase that intervenes between the subject head *key* and the verb.

(2) **The **key**[SG] to the <u>cabinets</u>[PL] **were**[PL] on the table.*

The attractor is often the closest noun in terms of the linear order, but this is not always the case, as illustrated in (3) (an example from Wagers et al., 2009).

(3) ***The drivers**[PL] who the <u>runner</u>[SG] **wave**[PL] to each morning honk back cheerfully.*

Errors of this kind have long been observed for languages like English and Latin and discussed in the context of agreement theories (Francis, 1986; Hale & Buck, 1903, p. 178; Quirk et al., 1985, p. 757). A seminal psycholinguistic study of Bock & Miller (1991) demonstrated that attraction errors in production can be elicited in laboratory settings with a sentence completion task. The results have been replicated in subsequent research, which also confirmed that the number attraction is characterized by an asymmetry: a plural attractor following a singular subject (e.g., *The key to the cabinets*…) is more likely to affect the agreement than a singular attractor following a plural subject (e.g., *The keys to the cabinet*…) (Eberhard, 1997; Häussler, 2012; Pearlmutter et al., 1999). In language comprehension, number attraction may manifest in higher error rates and prolonged response times in acceptability rating (Häussler, 2012). Agreement attraction has not been found for nouns bearing only superficial similarity to plural forms (e.g., *cruise* resembling *crews* or *course* resembling *courts*) (Bock & Eberhard, 1993; Häussler, 2012), which suggests that agreement processing goes deeper than a surface-level phonological analysis.

4.3 Number morphology

Are morphologically complex words stored as a whole or does the mental lexicon consist primarily of morphemes and rules for combining them? Research on grammatical number processing has been an important source of evidence used to address questions about the status of morphology in the representation of words (Alfonso Caramazza et al., 1988; Jackendoff, 1975; Pinker & Prince, 1991). The treatment of grammatical number in production and comprehension has been relevant for this discussion because number tends to be marked by morphological affixation, at least in languages like English, Dutch or French, from which much of psycholinguistic data was initially drawn.

Van Der Molen & Morton (1979) investigated the processing of plural morphology in English with a word recall experiment. Participants watched sequences of six words displayed from slides. After each sequence they were asked to write down the words they just saw. The sequences contained singular and plural nouns as well as verbs, adjectives and prepositions. The results showed that participants sometimes wrongly recalled plural nouns as singular and singular nouns as plural. The omission of plural morphology from a previously plural noun in a recalled sequence increased the likelihood of plural morphology erroneously "showing up" on a previously singular noun in the same sequence. This was taken as evidence of the separability of the number marker from the noun stem during processing. The marker occasionally detaches from the stem and then gets suffixed to a different available lexical item. In some cases, this transfer of plural morphology resulted in pluralizing an irregular noun (e.g., recalling *woman* as *women*), which suggests a more abstract representation of the unit encoding number. However, it is unclear whether the separable number morpheme activated number semantics, because sometimes the transfer resulted in attaching the plural *-s* suffix to a verb (e.g., recalling *knows* instead of *know*). Given that in English the *-s* ending on a verb marks singular agreement, it is likely that the primary representation of the number morpheme by the participants in the experiment was not semantic.

The processing of number morphology has also been investigated in studies manipulating the corpus frequencies of singular and plural nouns. Baayen, Dijkstra & Schreuder (1997) conducted lexical decision experiments with native speakers of Dutch. They found no difference between singular nouns with the same base frequency (cumulative frequency of the singular and plural forms of a noun) but different surface frequencies. On the other hand, when the surface frequency of singulars was kept the same, manipulating the base frequency resulted in different reaction times. Plural nouns differed from their singular counterparts (showing a surface frequency effect) only when their surface frequency was relatively high. The authors proposed a dual-route model to account for the data. According to the model, words usually activate both the full form representation and their constituent morphemes, if a morphological split is possible. Both routes proceed in parallel. Which route influences the recognition process more depends on a number of factors, including frequency. Plural forms (especially those with lower surface frequency) are morphologically decomposed into stem and number suffix, so singular forms (identical to stems in Dutch and in English) benefit from extra exposure. The Dutch results were successfully replicated for Italian in Baayen, Burani & Schreuder (1997), despite morphological differences between the two languages (in Italian both singulars and plurals bear an overt number-marking suffix). However, the cross-linguistic applicability of the dual-route model was put into question by Sereno & Jongman (1997). Their experiments with native English speakers showed a surface frequency effect for both singulars and plurals, providing no evidence for morphological separability of the number affix in language comprehension. New et al. (2004) conducted a series of lexical decision experiments with French and English singular and plural nouns to test the predictions of the dual-route model in French and to try to replicate the results of Sereno & Jongman (1997) in English. For French, the results aligned with the Dutch study of Baayen, Dijkstra & Schreuder (1997). Singulars showed a clear base frequency effect and no surface frequency effect. There was a (partial) surface frequency effect for plurals. For English, the data were less clear (singulars showed a weak surface frequency effect in addition to a base effect).

More recently, Lück et al. (2006) conducted an auditory ERP experiment. Participants listened to German sentences containing nouns with correct or incorrect plural morphology, while the EEG signal of their brain activity was recorded. The plural markers were the highly regular suffix -*s* and the half-irregular suffix -*n*. Overapplication of the -*s* suffix to normally -*n* marked words resulted in an increased amplitude of the LAN and P600 components associated with morphosyntactic violations and sentence-level reanalysis and repair, respectively. This was taken as evidence for the independent status of -*s* as a plural morpheme that connects with the stem through a combinatorial, rule-based mechanism. An incorrect -*s* combination was treated like a structural error. In contrast, application of the -*n* suffix to German surnames, normally -*s* marked, resulted in an increased amplitude of the N400 component associated with lexical anomalies. This was taken as evidence that (at least some) -*n* marked plural forms are treated as undecomposable wholes, with no attempted combinatorial process. However, a group of loan words, normally -*s* marked, erroneously displayed in the experiment with the -*n* suffix, showed a mixture of both outcomes, with increased amplitudes for the LAN plus P600 components as well as a greater N400. This shows that the status of -*n* marked plural forms as decomposable or not may depend on the lexical properties of the stem, especially in auditory processing, where the stem appears before the suffix.

4.4 Conceptual representation of grammatical number (mental simulation)

A separate area of research on the processing of grammatical number is the conceptual interpretation of the numerical information in linguistic expressions. Is number in language more like an abstract feature used exclusively in logical reasoning or is it associated with more specific, perhaps image-like, conceptualizations? Questions like this make grammatical number relevant for a wider debate about the nature of conceptual knowledge (Barsalou, 1999; Bergen, 2005; Connell, 2007; Zwaan, 2016; Zwaan & Pecher, 2012). Two major approaches are in competition here. On the one hand, non-perceptual theories assume that cognition uses amodal representations of concepts, separate from sensory perceptions. On the other hand, perceptual theories propose that conceptual cognition involves activating mental representations with qualities close to perceptual experiences.[9]

Understanding a concept, according to the perceptual approach, is like performing an internal simulation of the conceptualized idea. The mental simulation hypothesis predicts that, during language comprehension, a simulation associated with the meaning of an utterance should lead to inferring information neither expressed directly nor made available through simple lexical associations. For instance, reading a sentence about pencils in a cup, a comprehender should conceptualize those objects differently than when reading about pencils in a drawer. Due to image-like qualities, the mental simulation of the former can be expected to entail a vertical orientation, whereas the latter might activate the representation of a horizontal position. Such predictions have been tested empirically, with a sentence-picture verification task being a

[9] Perceptual and amodal approaches are not necessarily mutually incompatible. For example, based on the existence of categories uniting perceptually dissimilar objects (e.g., seafood) and on problems with recognizing non-prototypical members of a category exhibited by semantic dementia patients, Patterson, Nestor & Rogers (2007) suggested that conceptual knowledge relies on both a distributed network of somato-sensory brain areas (a perceptual component) and on a hub located in the temporal poles with converging connections from the distributed network (an amodal component).

common technique employed by researchers. Stanfield & Zwaan (2001) asked participants to read sentences followed by an image. The participants decided for each picture whether the object it depicted was mentioned in the preceding sentence. Crucially, sentences entailed (but did not state explicitly) the orientation of the object that either matched or mismatched its visual orientation in the picture. Results showed that participants responded on average faster in the matching condition. This is consistent with the hypothesis that language comprehension involves mental simulations containing perceptual details, like object orientation. A similar study by Zwaan, Stanfield & Yaxley (2002) revealed that participants responded faster to pictures matching the preceding sentence in terms of the shape of the described object (e.g., a picture of an eagle with outstretched wings following a sentence describing an eagle in flight). This suggests that shape, like orientation, may be part of the mental simulation of sentence meaning.

Is numerosity included in a mental simulation? Patson, George & Warren (2014) employed a sentence-picture verification task to study the possible role of grammatical number in forming perceptual simulations. They presented participants with English sentences containing critical noun phrases (singulars, plurals with the numeral *two* or plurals with no numeral). Sentences were followed by pictures of either a single object, two objects or a small group. Participants decided whether each picture contained objects named in the preceding sentence (ignoring the number). Responses were faster to number-matching pictures for singular and two-quantified plural expressions, but there was no number-matching effect for plurals without a numeral. The authors concluded that numerosity is part of the mental representation of a noun phrase's meaning, although plural nouns not accompanied by a numeral are unspecified in terms of number. There is evidence, however, that plural nouns may evoke a mental image of multiple elements even without the presence of a numeral. Patson (2016a) conducted another sentence-picture experiment using plural nouns in sentences that characterized their referents as either spatially distributed (e.g., *The breeze scattered the leaves*) or spatially gathered (e.g., *The gardener raked up the leaves*). The sentences were followed by pictures presenting groups of objects in spatial configurations that either matched or mismatched the description in the preceding sentence. Again, participants had to decide whether the objects in the pictures were mentioned in the sentences. The analysis of response times revealed that participants had more problems with the spatially mismatching trials in comparison to the matching ones. This suggested that comprehenders constructed a relatively detailed mental representation of the meaning of plural expressions, including the numerosity and the spatial arrangement of set elements.

5 Research problems

The research outlined above provides some insight into how number morphology and agreement is handled by the parser and what kind of conceptual numerical representations are built by language comprehenders. One aspect of number processing that has attracted relatively little attention is the processing stage linking morphosyntactic analysis with semantic interpretation, namely when and how exactly conceptual number information is extracted from number forms and combined with the larger context resulting in the ultimate numerical interpretation.

The present study aimed at investigating further the extraction and representation of the quantity concepts connected with grammatical singularity and plurality. The research focused on three areas.

5.1 Form-meaning mismatches

In some cases, the grammatical number of a word is at odds with its intended numerical meaning. This form-meaning mismatch applies, for instance, to a subset of nouns that refer to groups with salient members, e.g., *drużyna* 'team'. Such words are known as ***collectives***. In some dialects of English, the notional plurality of collective nouns is reflected in the option to choose plural verb agreement for a grammatically singular collective subject (Bock et al., 2006; Humphreys & Bock, 2005; Levin, 2001), as illustrated in sentence (4).

(4) *The committee has/have finally made a decision.*

Another group of number-mismatching words are ***pluralia tantum*** (e.g., *glasses*). Although their grammatical number is always plural, they can be used to refer to a single object (e.g., a single pair of glasses). One more category of words with an opaque number, ***mass nouns*** (e.g., *snow*), are grammatically singular by default, although this value is not related in any obvious way to their meaning. They typically denote some unspecified quantity of unindividuated substance or abstract concepts. Unlike ordinary singulars, they cannot take the indefinite article without a significant change in meaning.

The number mismatch constitutes a potential challenge for language comprehenders. An interesting question is how language users deal with the conflict inherent in these words, specifically, whether the initial conceptual numerical representation of their referents is driven primarily by the grammatical designation or the lexical semantics.

5.2 Morphological markedness

During language comprehension, a proper activation of numerical concepts depends on the correct recognition of the number form. In many languages, grammatical number is expressed through a morphological affix on the noun (see Section 2.2 of the present chapter). However, one of the number values is often expressed through a *lack* of an overt marker, distinguishing it from the marked forms (e.g., English *dog-Ø* vs *dog-s*). Cross-linguistically, if a language distinguishes singular and plural number values, plural forms are typically marked, while singular forms tend to be unmarked (Greenberg, 1963, Universal 35). This contrast may have consequences for the processing of grammatical number.

Some evidence for a processing asymmetry between (marked) plural and (unmarked) singular number has been uncovered by research on agreement errors, where plural nouns were demonstrated to be stronger attractors than singular nouns (Bock & Miller, 1991; Pearlmutter et al., 1999), as discussed in Section 4.2 of the present chapter. Polish constitutes an interesting test-case for investigating the role of morphological markedness in accessing number meaning because it offers both morphologically marked (e.g., *krow-a* ‘cow-NOM.SNG’) and unmarked (e.g., *kot-Ø* ‘cat-NOM.SG’) singular nouns. Contrasting those two types of singular nouns with each other and with plural nouns should shed more light on the effect of morphological marking on the processing of grammatical number.

5.3 Compositional semantics

The intended number interpretation of nominal phrases is based only partly on the form of the noun itself. Additional numerical clues in a sentence are often provided through quantificational elements, which may include numerals, determiners, quantifiers or adverbs. In an extreme case, morphological distinctions between singular and plural forms may be neutralized and the sentential context may be necessary to arrive at the intended number interpretation.

(5) *The shepherd lost his only sheep/all of his sheep.*

Number interpretation may also depend on the type of expression and its logical structure. For instance, in generic sentences, a singular noun does not refer to a single entity, denoting instead an entire class.

(6) *The tiger is a dangerous animal.*

Establishing how numerical concepts are activated during the interpretation of various types of sentences provides an opportunity to learn more about the timing of grammatical number processing with respect to semantic composition, especially regarding the influence of scope-taking logical operators (e.g., negation, quantifiers).

5.3.1 Negation

In certain contexts, like questions (7a), conditional constructions (7b) and, most notably, negative sentences (7c), plural nouns are typically understood as referring not to a group of two or more individuals (***exclusive plural interpretation***) but to any number of individuals, one or many, as long as it is not zero (***inclusive plural interpretation***).

(7) a. *Have you seen any squirrels?*
[I can answer “yes” truthfully even if I saw just one squirrel.]

b. *If you see any squirrels, let me know.*
[The speaker wants to be notified even if only one squirrel is seen.]

c. *I haven't seen any squirrels.*
[The sentence is false even if I saw only one squirrel.]

Examining the effect of sentential negation on the numerical interpretation of a word is particularly interesting because of its ability to reverse the logical value of the whole sentence, which, as some studies suggest (Fischler et al., 1983; Lüdtke et al., 2008), may happen at a later stage, after the primary affirmative version of the expression is evaluated. Is a plural noun in the scope of sentential negation interpreted inclusively immediately after it is encountered, or is the early interpretation exclusive? An answer to this question has consequences for models of language parsing.

5.3.2 Quantifiers

Negation is not the only sentence element with a potential to override the basic conceptual value of a grammatical number marker. The numerical interpretation of a noun can also depend on the presence of quantifiers. Sentences (8) and (9) are similar, both containing a singular noun. The numerical reading of the noun in each sentence, however, differs.

(8) *Together, the kids bought <u>a present</u>.*

(9) *Every kid bought <u>a present</u>.*

The conceptual representation generated during language comprehension by the singular noun *present* is likely to involve just one object in sentence (8), but multiple objects (several presents) in sentence (9). Patson & Warren (2010) provided experimental evidence that this is indeed the case (see Section 2 of Chapter VI for more details). Studying the interpretation of singular nouns in the scope of various kinds of distributive quantifiers can provide an opportunity to better understand the process of arriving at a contextually-determined numerical interpretation of nouns embedded in sentences.

6 Methodology

Examining the three areas of grammatical number processing outlined above requires experimental methods sensitive to quantity concepts and, at the same time, capable of tapping into early automatic responses to the presented stimuli. Research on general numerical cognition provides promising diagnostics satisfying those criteria. Three interference phenomena related to number processing have been chosen as the basis of the techniques used in the experiments reported here: the numerical Stroop effect, the SNARC effect and the size congruity effect. Although all three have been well documented in the cognitive science literature, their potential to study grammatical number in language remains still underexplored. A secondary, methodological, goal of the current work was to provide more information about their validity for future psycholinguistic studies. The three phenomena are characterized below.

6.1 Numerical Stroop effect

Stroop effect (named after John Ridley Stroop, one of the early researchers investigating this phenomenon) results from difficulty with the simultaneous processing of conflicting information coming from different sources (Jaensch, 1929; Jensen & Rohwer, 1966; MacLeod, 1991; Stroop, 1935). The classic Stroop effect occurs in experiments involving color words. When the color of the font is incongruent with the meaning of the word (e.g., the word *red* written in green font), naming the font color while ignoring the word's meaning is more difficult than when the font color and the meaning are congruent (e.g., the word *red* in red font) or when the second dimension is removed altogether (e.g., geometric shapes displayed in different colors). Stroop-interference experiments demonstrate that some features of stimuli are activated automatically, even when they are irrelevant for the task at hand. A kind of Stroop effect exists for symbolic representations of numbers, like digits (*7*) or numerals (*seven*). Counting instances of number words or digits presented visually takes more time when the visual numerosity is incongruent with the numerical value (e.g., symbol *2* repeated four times: *2 2 2 2*) than in congruent or control conditions (Flowers, Warner & Polansky 1979; Naparstek & Henik 2010; Pavese & Umiltà 1998; Windes 1968).

The numerical Stroop interference task has rarely been used in research on grammatical number processing, although a few studies using a Stroop-based technique exist. Berent et al. (2005) presented participants (native Hebrew speakers) with singular and plural Hebrew nouns displayed on a computer screen either once (visually single) or repeated twice (visually double). Meaningless strings of repeated letters were used for control. Participants were asked to assess how many tokens they saw on the screen on each trial. When the morphological number of the word was incongruent with the visual numerosity, the participants' responses were significantly slower than for control items.[10] This Stroop-like interference effect was interpreted as suggesting that number value is extracted automatically from word forms.[11] A similar Stroop-like effect has been obtained for English by Patson & Warren (2010), who modified the technique to make it applicable to words presented in sentential contexts. Subjects in their study read sentences displayed in the self-paced reading format in one- or two-word chunks. Their task was to decide whether the final chunk of each sentence contained one or two words by pressing a button. The final chunk of critical sentences was always one word (for fillers it was always two words), so the expected answer for critical trials was always "one". The critical noun was either plural or singular. The results showed that for plural nouns the "one" answers were on average longer than for singular nouns, which indicates the presence of an interference.

6.2 SNARC effect

Another well-documented phenomenon lies at the intersection of numerical cognition and the processing of spatial relations. In a study by Dehaene, Bossini, & Giraux (1993), participants performing a number-related task were on average faster to respond to small numbers using the left hand and to big numbers using the right hand. The authors named the phenomenon ***spatial-numerical association of response codes (SNARC)***. The effect was sensitive to

[10] This effect was obtained only for grammatically plural words, i.e., when a word with a plural suffix was presented as a single token (e.g., *dogs*), the responses were considerably longer than when it was presented as two tokens (e.g., *dogs dogs*). Singulars did not differ significantly from the control.

[11] Possibly through number morphology alone because in one of the experiments the effect was found for meaningless nonwords with number marking.

relative, rather than absolute, numerical values.[12] It also depended on the reading and writing habits of participants, as it was much weaker or even reversed for Iranian subjects using a right-to-left writing system. Since then, SNARC has been replicated many times. It has been found in auditory as well as visual modality, for Arabic digits and for number words (Nuerk et al., 2005). The effect has been found both for tasks where the numerical value was directly relevant, like magnitude comparison (Gevers et al., 2006), and for tasks involving processing attributes of the stimulus independent of its numerical value, like size (Fitousi et al., 2009) or color (Keus & Schwarz, 2005), suggesting that the phenomenon is sensitive to information extracted rapidly and automatically. However, the picture is not entirely clear. The degree of automation seems to vary based on the type of task and the form of the stimulus. Some studies failed to find the effect in tasks involving the processing of "shallow" surface features. Röttger & Domahs (2015) carefully tested the influence of the task demands on the SNARC effect for processing number words. They gave participants four kinds of tasks using written German numerals as stimuli. The tasks were designed to test different levels of processing: deciding whether the word was written in italics (visual features); deciding whether the stimulus was a real German word (lexical status); deciding whether the word represented an even or odd number (parity semantics) or deciding whether the word represented a quantity larger or smaller than five (quantity semantics). No SNARC effect was found for the tasks involving focusing on visual or lexical features, however the effect was present for both parity- and quantity-related tasks. Number words seem more sensitive to the type of task than digits, as demonstrated in phoneme monitoring experiments (Fias, 2001; Fias, Brysbaert, Geypens, & d'Ydewalle, 1996).

In neurocognitive studies, SNARC has been correlated with activity in the intraparietal sulcus, close to an area independently known for its involvement in numerical processing and some aspects of spatial cognition (Cutini et al., 2014; Hubbard et al., 2005; Nieder & Dehaene, 2009). A correlation between SNARC and the ability to perform mental spatial operations has also been found. Participants who performed better on a 2D rotation task showed an attenuated SNARC effect, in contrast to slower 2D rotation performers (Viarouge et al., 2014).

[12] Numbers 4 and 5 received faster responses with the right hand when they were tested in the range 0-5 and with the left hand in the range 4-9.

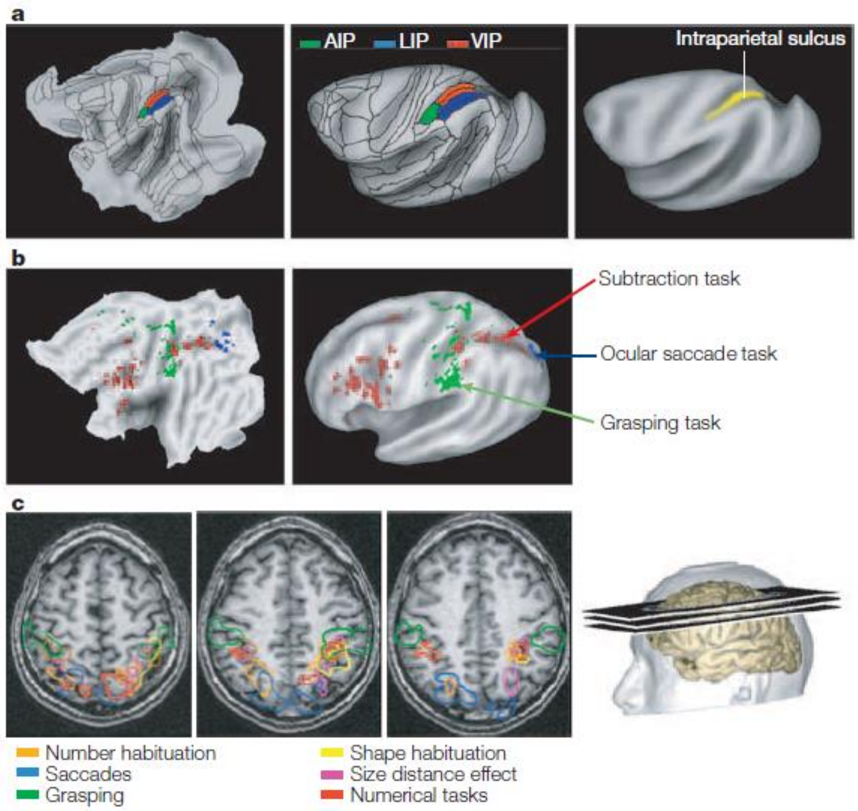

Figure 2: Location of numerical processing relative to the regions of the intraparietal sulcus involved in space and grasping (copied from Hubbard, Piazza, Pinel & Dehaene, 2005, p. 442, Figure 3).

The existence of the SNARC effect provides evidence for a link between numerical and spatial cognition. More specifically, it has been used as an argument in favor of the mental number line hypothesis, i.e., the idea that magnitudes associated with numbers are represented mentally as if on an imaginary line, typically with small numbers on the left and large numbers on the right (Dehaene et al., 1993; Göbel et al., 2011; Pavese & Umiltà, 1998). A characteristic property of the SNARC effect is its flexibility. The fact that the direction of SNARC can be altered, observed already by Dehaene et al. (1993), has been confirmed in other studies, for instance by Shaki, Fischer, & Petrusic (2009) working with Arabic and Hebrew speakers. A vertical SNARC effect has been reported by Schwarz & Keus (2004) and Ito & Hatta (2004). Such results suggest that even though number processing is likely supported by spatial cognition, the mental visualization does not have to be in the form of a straight horizontal number line running from left to right. Effects similar to SNARC have also been discovered for non-numerical stimuli that tend to occur in a particular order, like letters of the alphabet or names of the months (Gevers et al., 2003). This points to the presence of a more general cognitive strategy of arranging various mental representations (not only numbers) on a line in imaginary space, perhaps to optimize the usage of working memory or motor responses.

The SNARC effect has been successfully demonstrated for grammatical number. Röttger & Domahs (2015) conducted an experiment with singular and plural German nouns. They used four tasks probing different levels of processing (similar to the experiment with numerals described above). Participants were asked to decide whether the stimulus was written in italics (visual features) or whether it was an existing German word (lexical status). The two remaining tasks were semantic and involved deciding whether the noun denoted an animate entity (animacy semantics) or whether it denoted one or more than one thing (number semantics). The analysis of response times indicated that participants exhibited a left-hand preference for singular nouns and a right-hand preference for plural nouns. This pattern resembled the classic SNARC effect for small and large numbers and was consistent with the possibility that singular nouns (denoting a small amount) are linked with the left end of the mental number line, while plural nouns (activating the concept of a big quantity) are linked with the right end. The effect was statistically significant only for the task requiring direct access to number semantics (i.e., deciding whether a given noun names one or more than one entity).

6.3 Size congruity effect

A different mental mechanism connects numerical cognition with the processing of size. Moyer & Landauer (1967) were among the first to provide a clue of this connection by demonstrating that visual size discrimination and number magnitude determination are subject to the same distance effect. Specifically, they showed that comparing the numerical magnitudes of two digits resembles comparing the lengths of two lines in that in both cases participants' responses become faster as the distance between the compared stimuli increases.

An important development was the discovery of a numerical variant of an interference phenomenon known as the ***size congruity effect (SCE)***. One of the first researchers to study the classic size congruity effect was Paivio (1975), who showed participants pairs of pictures depicting animals or objects that differed in sizes in real life (e.g., an ant vs. a dog). The pictures themselves appeared in different sizes so that sometimes the picture of the smaller object was visually bigger than the picture of the larger object (the incongruent condition) or vice versa (the congruent condition). Participants' task was to indicate which object is larger in real life while ignoring the sizes of the pictures. The responses were faster when the picture sizes matched the real-life sizes. A similar result was obtained for small- and big-font words naming various objects. Henik and Tzelgov (1982) conducted a magnitude comparison experiment using pairs of Arabic digits of varying font sizes. The numerical and visual magnitudes were either congruent (e.g., 3 vs. **5**) or incongruent (e.g., **3** vs. 5). The average response times in the congruent condition were faster than in the incongruent condition. This interference effect has been replicated in subsequent studies both with digits and number words (Besner & Coltheart, 1979; Cohen Kadosh et al., 2007; Foltz et al., 1984). The existence of the numerical SCE provides convincing evidence that the processing of numbers and the processing of size make use of shared cognitive resources. This affinity may be even more general, because a similar congruity effect has been found between number and luminance, another continuous physical magnitude (Cohen Kadosh & Henik, 2006).

To my knowledge, no paper describing a size congruity effect for grammatical number has been published. However, if interpreting number in language gives rise to a mental representation of quantity, it should also activate size information. After all, multiple dogs constitute a perceptually larger object than a single dog. For this reason, the size congruity effect can, like the numerical Stroop effect and the SNARC effect, be used as a potential diagnostic for which numerical concepts are automatically extracted from words given their grammatical number, lexical semantics and sentential context.

7 Thesis outline

Six psycholinguistic experiments with native speakers of Polish have been conducted using techniques based on the three interference phenomena related to numerical cognition described above. Their goal was to investigate the specific questions in number processing research described in Section 5 of the present chapter. The rest of the thesis provides a description of the design and results of each experiment followed by the interpretation of the data. The thesis ends with a summary and a general discussion of the findings as well as the conclusions regarding the chosen experimental methods. Ideas for possible future research are also presented.

Chapter II discusses Experiment 1 and Experiment 2, both designed to examine the effect of a form-meaning mismatch on the processing of grammatical number. Specifically, the early automatic interpretation of collective nouns (e.g., *team*) was contrasted with the interpretation of non-collective singular and plural nouns. This was done by testing the capacity of different nouns to produce the SNARC effect and the size congruity effect.

Chapter III discusses Experiment 3, which explored the role of morphological markedness in grammatical number processing. The experiment tested the possibility that an overt number ending may facilitate the access to number information in comparison to zero-marked forms. This was done by testing the capacity of different number markings to produce the numerical Stroop effect.

Chapter IV discusses Experiment 4, which combined the exploration of form-meaning mismatches and morphological markedness in grammatical number processing. Collective nouns were used once again, but this time the stimuli included also other words with a conflict between grammatical number and numerical interpretation, namely mass nouns (e.g., *sand*) and *pluralia tantum* (e.g., *scissors*). An additional manipulation was the type of number marking (overt vs. zero ending) on nouns. The technique was again based on the numerical Stroop effect.

Chapter V discusses Experiment 5, the first of two experiments investigating grammatical number processing in context. The experiment delved into the influence of sentential negation on the numerical representation of grammatically plural nouns. This was done by placing nouns in affirmative and negative sentences. The technique was again based on the numerical Stroop effect.

Chapter VI discusses Experiment 6, the final experiment investigating the effects of two types of distributive quantifiers (distributing over objects and events) on the processing of grammatically singular nouns. This was done by placing nouns in expressions with quantifiers interpreted as collective, distributive over objects and distributive over events (iterative). The technique was again based on the numerical Stroop effect.

Chapter VII summarizes the main results for each area and discusses their significance before moving on to methodological conclusions and then to ideas for future research.

The overall aim of this thesis is to contribute to psycholinguistic theories of language comprehension by studying how language users extract number information and represent the numerosity of referents based on grammatical number and its interaction with other sentence elements. In an even wider context, the data obtained through the experiments may lead to a better understanding of the relations between language and other cognitive systems, specifically the system of numerical cognition. Finally, by applying techniques based on number-interference phenomena (the numerical Stroop effect, the SNARC effect and the size congruity effect), the thesis offers a potential contribution to the methodology of experimental language research.

CHAPTER II

NUMBER MISMATCH

1 Introduction and chapter overview

Although linking number form with number meaning seems like a straightforward and intuitive task, on a closer inspection it turns out to be problematic. It is true that singular forms refer primarily to single and plural forms to multiple entities, but on some uses this strict relation does not hold. Sometimes a conflict arises between the value of a word's grammatical number and its lexical meaning. ***Collective nouns*** are a class of words found in many languages characterized by an inherent (lexical) plurality. The contrast between collective and non-collective nouns, just like the contrast between singular and plural nouns, is related to the number of entities under discussion. However, the numerical values from those two categories seem to be at odds. A grammatically singular collective noun, like the English word *committee*, refers to a (single) collection with (multiple) salient elements. Proper comprehension of a collective noun requires the ability to reconcile those two sources of information and select the correct concept. How do language comprehenders represent the denotation of collective singular nouns and how do those representations compare to non-collective singular and plural nouns?

Studying the processing of nouns with a form-meaning mismatch can shed more light on the mechanisms through which language comprehenders create a numerical interpretation of words and the role of grammatical, lexical and pragmatic factors in those mechanisms. The two experiments described in the present chapter, Experiment 1 and Experiment 2, investigated the processing of collective singular (e.g., *army*), non-collective singular (e.g., *soldier*) and plural (e.g., *soldiers*) nouns. Two number-sensitive phenomena related to numerical cognition (SNARC and size congruity effect) were used as number meaning diagnostics to directly compare grammatical singularity and plurality with collectivity.

The present chapter starts with an overview of the past studies offering some insight into the numerical interpretation and processing of collective nouns. The limitation of the past research is pointed out. After that, detailed descriptions of both experiments are provided, including the specific method and research questions, materials, procedure, data analysis and results. The chapter ends with the general summary and discussion.

2 Background: Conceptual representation of collectivity

Grammatically singular collective words, like *army*, can refer to a single entity (a collection) or to multiple things (elements of a collection). Studies using ***number judgment*** tests to quantify the likelihood of both uses can be found in the literature. Bock & Eberhard (1993, part of Experiment 4) showed participants a list of collective and non-collective English nouns that were either singular or plural. The participants were asked to indicate how many things each word represents ("If you were thinking about the X, would you be thinking about one thing or more than one thing?"). The test revealed that collective singulars were significantly more likely to be associated with the "more than one thing" answer than non-collective singulars, although this answer constituted only 41% of all responses for this noun type (in contrast to around 90% of "more than one thing" responses for grammatically plural nouns). Nenonen & Niemi (2010) conducted a similar judgment test for several classes of Finnish nouns, including derivationally created collectives. The results showed again that participants allowed plural referents for grammatically singular collective nouns, though less readily than in Bock & Eberhard's English study: the "many things" answers constituted around 20% of responses in this condition.[13] Overall, a plural interpretation of collective singulars is generally available in the studied languages, although it is clearly not a dominant one.

Much of the empirical data relevant for the discussion on the conceptual representation of collective reference comes from research on number agreement. In English, grammatically singular collective subjects can appear with both singular and plural agreement morphology on the verb, like in sentence (10).

(10) *The committee* ***has/have*** *finally made a decision.*

An investigation of the agreement patterns for collectives in two major varieties of English can be found in Bock et al. (2006). Participants in a sentence completion test (British and American English speakers) were instructed to turn simple definite noun phrases containing different types of nouns into full sentences. Collective singular nouns were followed by plural verbs in around 14% of unambiguous continuations in contrast to the near lack of plural agreement continuations for ordinary singular nouns and nearly 100% of plural agreement continuations for plural nouns. A similar pattern was found in a corpus survey of American and British financial press. In the studied sample, collective singular nouns were followed by plural verbs in around 16% of cases. Thus the study confirmed that plural verb agreement for collective singular subjects is available as a regular option for the speakers of at least one variety of contemporary English,[14] although it is chosen less frequently than singular agreement. This relative freedom of verb agreement selection for singular collective subjects is called

[13] The authors report a considerable variability for individual collective nouns, which ranged from 0% to around 40% of the "many things" responses. This suggests that not all nouns commonly treated as collective by linguists may in fact have this status for the majority of speakers.

[14] There was a significant difference between language varieties in the sentence completion task: whereas British English respondents used plural verbs in approximately 20% of continuations for collective nouns, American English speakers used plural verbs only in 2.3% of continuations in this condition. Also in the corpus survey there was a difference across varieties: for the British corpus plural agreement was found in 26% of clauses with collective subjects compared to just 7% for the American corpus.

conceptual (or notional) agreement, reflecting the assumption that the choice of a singular or plural verb corresponds to different conceptualizations of collective noun referents.[15]

The method of ***agreement attraction*** elicitation (see Section 4.2 of Chapter I) has been applied to studying the processing of collective nouns, revealing a difference in the role of lexical collectivity and grammatical plurality in the computation of agreement. In Bock & Eberhard (1993, Experiment 4), participants listened to sentence fragments containing a subject and an attractor noun. Their task was to provide a continuation turning each fragment into a full sentence. The attractors were collective or non-collective nouns that could be grammatically singular or plural (e.g., *The condition of the fleet/fleets/ship/ships…*). The results showed that plural attractor nouns (e.g., *fleets/ships*) lead to agreement errors (a plural verb continuation for a singular subject) in a significant number of responses. Crucially, collective singulars (e.g., *fleet*) behaved just like non-collective singulars (e.g., *ship*) and did not disrupt the agreement process. The results were successfully replicated in Bock et al. (2001a). Assuming that number attraction is sensitive to the conceptual representation,[16] such outcome may indicate that the plural meaning of collective nouns either takes some time to compute or is not strong enough to "hijack" the agreement mechanism.

The number judgment and agreement studies reviewed above show that the referents of collective singular nouns can be construed as plural. It is not clear, however, how this conceptual plurality comes to be. One possibility is that a collective word is immediately recognized as such and both its readings (singular and plural) are activated simultaneously, competing for selection. Another possibility is that the initial automatic numerical interpretation of a collective singular is driven by its grammatical number alone. Under this

[15] The degree to which the variable agreement of collectives is semantically motivated is controversial (for an overview of the discussion, see Levin, 2001, especially pp. 28–32). Empirical support for the possibility that collective agreement is sensitive to number semantics has been provided by, e.g., Humphreys & Bock (2005), who manipulated the conceptual representation of entities denoted by collective nouns in an experiment by presenting their elements as spatially distributed (*The gang on the motorcycles…*) or collected (*The gang near the motorcycles…*). The participants turned sentence fragments containing collectives into full sentences. Plural verbs appeared in 74% of continuations following distributed construals in comparison to 67% following collected construals.

[16] This assumption contradicts the authors' own interpretation. Both Bock & Eberhard (1993) and Bock et al. (2001a) favor a strictly morphosyntactic explanation, where the semantic number of nouns has little influence on agreement in general. Subject-verb agreement is taken to be computed based mostly on the basis of grammatical (morphosyntactic) number information.

account, the conceptual plurality would be derived from the more primary singular interpretation (consistent with the grammatical number) by highlighting constituent parts, perhaps through a mechanism of profiling proposed by Lagnacker (1991, also discussed in Levin, 2001, p. 15). This process is likely pragmatic in nature. For example, in a typical conversation, highlighting individual "components" of a police team is more common than highlighting individual parts of a car. Hence, a construction like (11) is easy to understand, while a sentence like (12), with the intended meaning of "every single part of a car broke down", is not.

(11) *Police are baffled after a gang stole 150 T-shirts.*

[from British National Corpus Online]

(12) **The car have broken down.*

Under this view, initially there wouldn't be any plural component in the interpretation of collective nouns. The constituent parts of their referents would simply be more accessible for pragmatic reasoning than in the case of other nouns. A conceptual plurality, reflected in judgments and conceptual agreement, would only appear if the comprehender specifically focused on the components. In this respect, collective singulars would differ from grammatically plural nouns.

Previous research does not provide the type of data needed to distinguish between the two possibilities. Number judgment studies often ask simply about the offline (conscious) interpretation of collective nouns. This may conceal the influence of the automatic activation of numerical concepts at early stages of lexical access, which may stay in conflict with the ultimate number interpretation. In agreement studies, it is not clear whether the results reflect conceptual representations or measure purely morphosyntactic processes. General understanding of how the mismatch between lexical collectivity and grammatical number is processed may benefit from applying tools sensitive to number semantics at early automatic processing stages. As described in the Methodology section (Section 6 of Chapter I), techniques based on phenomena linked to numerical cognition seem promising. The two reaction time experiments reported in the present paper were designed to directly compare grammatically plural and singular non-collective nouns with collective nouns using the

SNARC effect and the size congruity effect, two number-sensitive phenomena well documented in the literature on numerical cognition.

3 Experiment 1

3.1 Method

Both experiments make use of the same method combining two number-meaning diagnostics. The first diagnostic is the SNARC effect. As described in Chapter I (Section 6.2), Röttger & Domahs (2015) showed that responses to grammatically singular nouns are faster with the left hand and responses to plural nouns are faster with the right hand. This parallels the results for small and big numbers, known from research on numerical processing (Dehaene et al., 1993; Fitousi et al., 2009; Gevers et al., 2006; Keus & Schwarz, 2005).

The other number-meaning diagnostic used in the present experiments is the size congruity effect (SCE), also described in more detail in Chapter I (Section 6.3). In Henik and Tzelgov's (1982) experiment involving a magnitude comparison of visually big and small digits, response times were faster for the congruent condition (e.g., 3 vs. **5**) than in the incongruent condition (e.g., **3** vs. 5). To my knowledge, the possibility of a size congruity effect for grammatical number (or collectivity) has not yet been tested.

Fitousi, Shaki, & Algom (2009) designed a study to determine whether SCE and SNARC would interact, which would suggest a common processing stage. They asked participants to determine the font size of numbers (Arabic digits 1-9 except 5) displayed on the screen by pressing a left-hand or a right-hand key for large or small font (the assignment of responses to sides varied between blocks). The participants were asked to ignore the numerical value of the digit. There was a clear size congruity effect: answers for lower numbers (1-4) were given faster when they were displayed in small font and for higher numbers (6-9) responses were faster when they were displayed in large font. There was also a significant SNARC effect: numerically smaller numbers were responded to faster with the left button than the right button and for numerically large numbers the opposite was true. The authors found no statistical evidence in the data of any interaction between the two effects. Leaving aside the interpretation of this result, the study showed that the two effects can be elicited simultaneously in a single experiment, which was also attempted in Experiment 1 and Experiment 2 in the present work.

3.2 Research question and predictions

The goal of Experiment 1 was to investigate the early automatic processing of collective singular vs. non-collective singular and plural nouns, as measured by their capacity to produce a SNARC effect and a size congruity effect. This question was addressed in a semantic-number judgment experiment by manipulating the response hand, grammatical number and font size of collective and non-collective (henceforth "unitary") Polish nouns.

The predictions for unitary singulars and plurals were pretty straightforward, based on the results of previous SNARC (e.g., Röttger & Domahs, 2015) and SCE (e.g., Henik & Tzelgov, 1982) studies. Unitary singular nouns should activate the concept of "one", congruent with the left-hand side (SNARC) and with small font (SCE), whereas plural nouns should evoke the notion of "more than one", congruent with the right-hand side and with big font. Those predictions are visually represented in Figure 3.

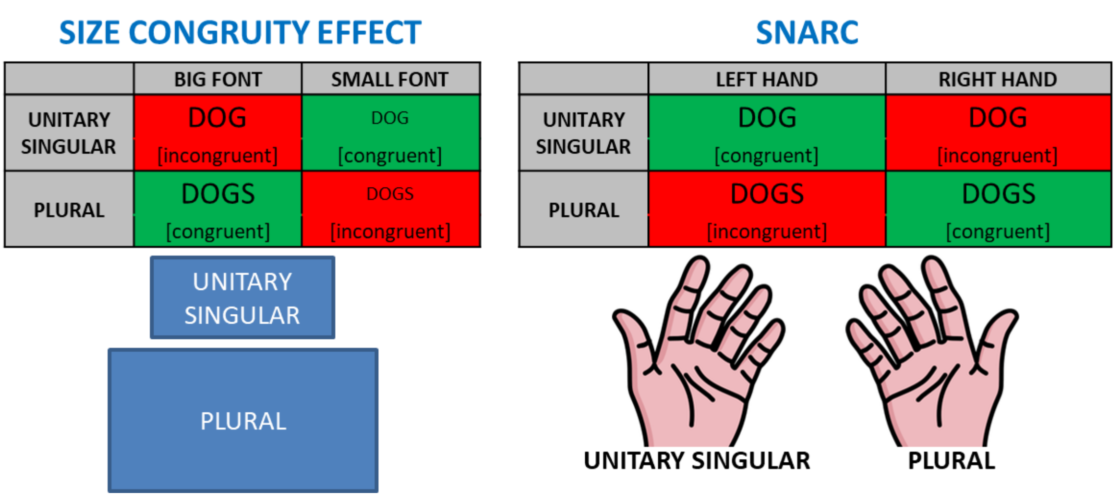

Figure 3: The congruent and incongruent conditions (SCE and SNARC) for unitary singular and plural nouns in Experiment 1.

The results for collective singulars were of particular interest. If the primary representation of their meaning involves conceptual multiplicity, they should pattern with plurals. If multiplicity is not a salient, directly accessible feature of their semantics and their initial reading is driven by their morphosyntactic designation (singular), they should behave like unitary singulars. If both construals (singular and plural) are initially activated, resulting in a conflict and competition, collective singulars can be expected to fall somewhere between unitary singulars and plurals in terms of their capacity to elicit SNARC and SCE.

3.3 Design

3.3.1 Materials

Thirty unitary singular nouns (e.g., *wilk* 'wolf') were selected for the experiment. Thirty plural forms were created from the singulars (e.g., *wilki* 'wolves'). Additionally, 20 collective singular nouns (e.g., *ławica* 'shoal') were chosen.

As demonstrated in (13), conceptual verb agreement with collective subjects does not exist in Polish.[17]

(13) *Komisja podjęła / *podjęli decyzję.*
committee made.SG / made.PL decision
'The committee has/have made a decision.'

The collective status of Polish nouns like *komisja* 'committee' can be demonstrated by their compatibility with predicates like *zebrać się* 'to gather', which normally require plural subjects (see examples (14), (15) and (16) below). This was used as a criterion during the selection of collective nouns for the experiment.

[17] In a study with native speakers of Russian, Lorimor et al. (2008) found that agreement attraction and conceptual agreement phenomena are much weaker in Russian than in English. The authors attributed this to the morphological richness of the former. The same account likely applies to Polish, another Slavic language with a rich inflectional morphology.

(14)	*Komisja*	*zebrała*	*się*	*w*	*południe.*	
	committee	gathered.SG	REFL	in	noon	
	‘The committee gathered at noon.’					
(15)	*Członkowie*	*komisji*	*zebrali*	*się*	*w*	*południe.*
	members	committee.GEN	gathered.PL	REFL	in	noon
	‘Committee members gathered at noon.’					
(16)	**Przewodnicząca*	*komisji*	*zebrała*	*się*	*w*	*południe.*
	chairwoman	committee.GEN	gathered.SG	REFL	in	noon

Plural equivalents for collective singulars were not created by simply pluralizing them. Instead, a plural form of a different unitary noun was selected for each collective singular, such that both lexemes were closely semantically related (e.g., plural *śledzie* ‘herrings’ for collective singular *ławica* ‘shoal’). This was done for two reasons. First, many Polish collective nouns show a case syncretism across grammatical number (e.g., *grup-y* ‘group-NOM.PL’ or ‘group-GEN.SG’). Such number ambiguity is easily disambiguated with context, but, in the present experiment, words were shown in isolation and the results hinged on a fast recognition and activation of number values. None of the plural forms used in the study was ambiguous in this way. The second reason was to avoid the possible difficulties with processing “doubly plural” forms like *teams*.

Overall, there were 100 nouns (60 unitary and 40 collective), 50 singular and 50 plural, each occurring in a big font and a small font condition as well as in a left-response hand and a right-response hand condition. This design resulted in 400 trials presented in 2 blocks. Every participant saw every item. The presentation order was fully randomized for every participant.

3.3.2 Procedure

The experiment was conducted on a standard PC computer using a 23.6 inch monitor (LG 24M35D-B) with the 1920x1080 resolution. With the distance of a participant from the screen of approximately 60 cm, a single character in the small font condition (50 pixels) subtended ~0.45° (horizontally) and ~0.75° (vertically) of visual angle, while a single character in the big font condition (150 pixels) subtended ~1.62° (horizontally) and ~2.39° (vertically) of visual angle.

The experimental procedure was based on the techniques presented in Röttger & Domahs (2015) and Fitousi et al. (2009), which used a pure SNARC effect and a combination of SNARC with SCE, respectively. At the beginning of each trial, five * symbols appeared at the center of the screen. The symbols were automatically replaced after 300 ms by an experimental stimulus. The stimulus was a singular or plural Polish noun displayed either in small font or big font. The participant's task was to determine whether the noun referred to one or more than one thing (a semantic-number judgment task) while ignoring the visual size of the stimulus. The stimulus remained on the screen until the participant made a decision by pressing the "z" or "/" key on a standard QWERTY keyboard corresponding to the answers "one" or "more than one". There was a 300 ms blank screen between trials.

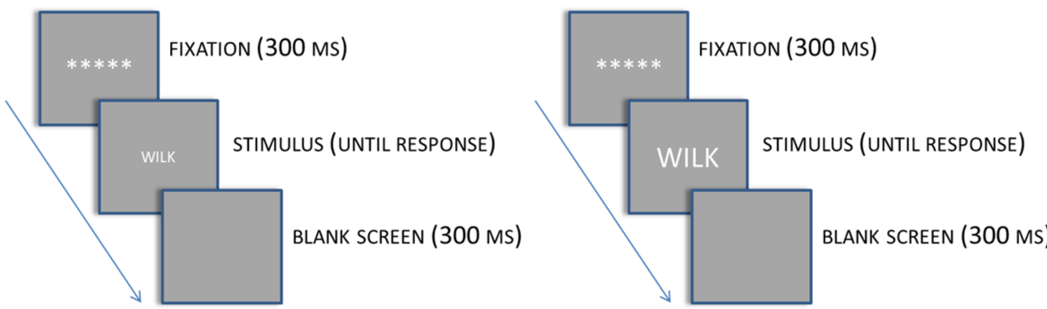

Figure 4: The structure of a trial in Experiment 1 in the small font and big font condition.

The experiment consisted of two blocks. The assignment of keys to responses changed after the first block (e.g., if "z" in Block 1 meant "more than one", in Block 2 it meant "one"). A message before each block informed the participant about the current assignment of keys. The order of key assignments in blocks was counterbalanced across participants. There were three breaks within each block. During a break the participant was encouraged to rest and resume the experiment by pressing a button. In each block, the experiment proper was preceded by a training session with 24 trials. The set of training items consisted of nouns balanced in terms of grammatical number, font size and response hand. None of the items used in the training session appeared later in the experiment proper. During the training session, a 1000 ms feedback was provided informing the participant whether the answer was correct or incorrect. During the experiment proper, feedback was provided only for incorrect responses.

The experiment was designed and presented using the PsychoPy software (version 1.84.2) (Peirce, 2007, 2009).

3.3.3 Participants

Twenty-two students of the Institute for English Studies of the University of Wrocław (9 women) took part in the experiment. Participants were all native speakers of Polish. The average age was 20.8 (*SD*=2.5).

3.4 Results: Accuracy

To determine the general availability of a plural meaning for collective nouns in Polish, the first analysis looked at the accuracy of responses for the three number types: collective singular, unitary singular and plural. The task required the participants to focus on the conceptual number of the noun ("Does the word name one or more than one thing?"). The grammatical number was expected to map in a straightforward way to the conceptual number in the case of unitary singulars and plurals, so the responses considered correct in those conditions were "one thing" and "more than one thing", respectively. The situation was more complicated for singular collectives, as discussed above. For the purposes of the analysis, answers for those nouns consistent with their grammatical number ("one thing") were coded as correct. Thus the accuracy measure represents the proportion of singular conceptualizations for collective and unitary singular nouns and plural conceptualizations for grammatically plural nouns.

The accuracy for collective singulars (*M*=79.3% *SE*=6.7) was considerably lower than the accuracy for unitary singulars (*M*=97.6% *SE*=0.6), meaning that participants chose the "one thing" answer more consistently for unitary than for collective nouns. The accuracy for plurals was very high (*M*=97.4% *SE*=0.6), meaning that participants almost always regarded them as referring to “more than one thing”. A one-way ANOVA test with Accuracy as the dependent variable and Number Type (collective singular, unitary singular, plural) as the independent factor confirmed that the difference was statistically significant ($F_1(2,42)=7.697$ $p=.001$ $\eta^2=.268$; $F_2(2,97)=330.346$ $p<.001$ $\eta^2=.872$).

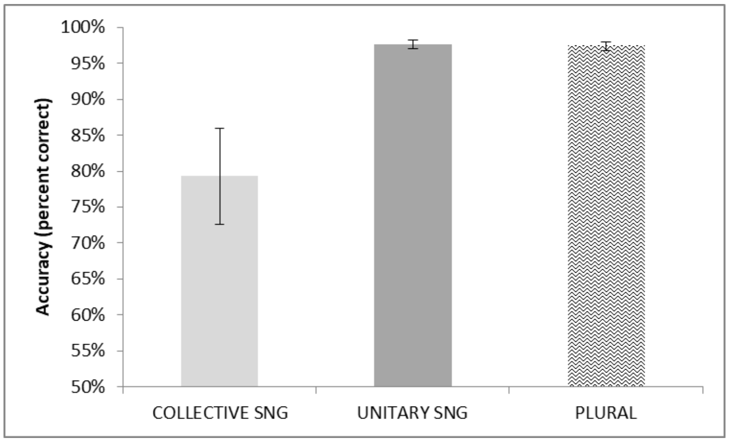

Figure 5: Average accuracy (percent correct) for collective singular, unitary singular and plural nouns in Experiment 1. Bars represent standard errors.

The variance among collective singulars was larger than for the other conditions. The least accurate collective singular items (*armia* ‘army’ and *brygada* ‘brigade’) received the singular (“one thing”) answer in 74% of cases, while for the most accurate collective item (*zbiór* ‘set’) the singular answer was given in 88% of cases (this was also the only word in this condition which could refer to an inanimate collection).

3.5 Results: Reaction Times

The data were cleaned first by removing all incorrect responses (with the exception of answers to collective singulars)[18] and then eliminating all trials with reaction times (RT) 3 standard deviations above and below the mean for every participant. This resulted in eliminating 184

[18] Because no response could be considered objectively wrong for collective singulars, all answers in this condition were included in the final analysis.

data points, which constituted 2.1% of correct responses. The remaining trials were subjected to tests performed with the SPSS software (version 22).

In order to test the research problem, a 3×2×2 ANOVA was conducted with RT as the dependent variable and the following independent factors:

- Number Type (collective singular, unitary singular, plural)
- Font Size (small, big)
- Response Hand (left, right)

Results of the ANOVA test are given in Table 2. Mean reaction times and accuracy in each condition are given in Table 3.

Table 2: ANOVA test results for Experiment 1.

	df		***F***		***p***		**Partial Eta Sq.**	
	SUBJECTS	ITEMS	SUBJECTS	ITEMS	SUBJECTS	ITEMS	SUBJECTS	ITEMS
NUM. TYPE	2, 42	2, 97	18.67	35.35	<.001*	<.001*	0.47	0.42
FONT SIZE	1, 21	1, 97	0.26	0.05	0.615	0.942	0.01	0.00
RESP. HAND	1, 21	1, 97	0.54	1.17	0.471	0.283	0.03	0.01
NUM. TYPE× FONT SIZE	2, 42	2, 97	0.66	0.19	0.520	0.828	0.03	0.00
NUM. TYPE× RESP. HAND	2, 42	2, 97	1.25	6.06	0.296	0.003*	0.06	0.11
FONT SIZE× RESP. HAND	1, 21	1, 97	0.45	0.14	0.508	0.712	0.02	0.00
NUM. TYPE× FONT SIZE× RESP. HAND	2, 42	2, 97	0.22	0.11	0.802	0.893	0.01	0.00

Table 3: Mean reaction times (ms) and accuracy (percent correct) in all conditions in Experiment 1. Standard errors in parentheses.

NUMBER TYPE	FONT SIZE	RESPONSE HAND					
		Left		*Right*		*Congruity (Left-Right)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Collective Sng	*Small*	854 (47)	80.7% (7.0)	910 (54)	77.0% (6.7)	-56	3.7
	Big	853 (45)	80.5% (6.7)	902 (59)	78.9% (6.9)	-49	1.6
Unitary Sng	*Small*	772 (41)	98.0% (0.8)	784 (42)	97.9% (0.8)	-12	0.1
	Big	776 (38)	97.4% (1.0)	789 (43)	97.0% (0.7)	-13	0.4
Plural	*Small*	821 (47)	97.5% (0.6)	802 (35)	97.0% (0.7)	19	0.5
	Big	818 (46)	97.5% (0.7)	779 (32)	97.6% (0.6)	39	-0.1

3.5.1 Number type effect

The main effect of Number Type was significant (see Table 2). Responses to collective singular nouns were on average longest (*M*=880 ms *SE*=45), followed by responses to plural nouns (*M*=805 ms *SE*=38) and unitary singular nouns (*M*=780 ms *SE*=38).

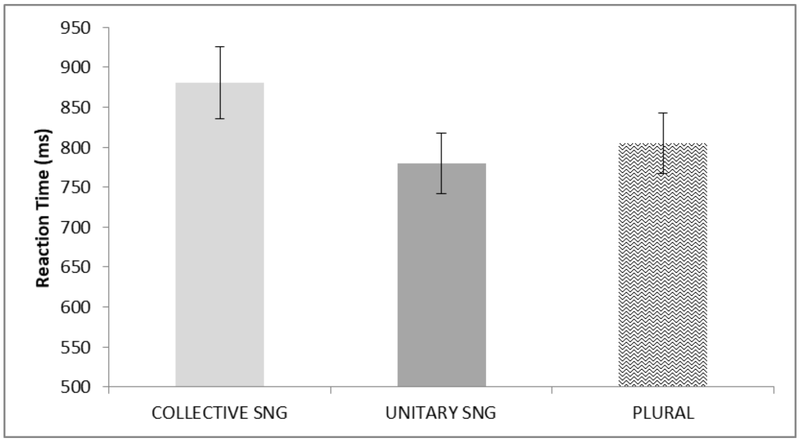

Figure 6: Reaction times (ms) for collective singular, unitary singular and plural nouns in Experiment 1. Bars represent standard errors.

As stated above, because no answer for collective singulars could be considered objectively incorrect, all responses in this condition were included in the final analysis. To check for a possible difference in the time needed to conceptualize a collective as singular or plural the average reaction times for the two types of answer within this condition were computed. The "more than one thing" responses were on average slightly longer (1168 ms) than the "one thing" responses (951 ms), indicating that a plural construal for collectives requires more time to compute.

No other main effect was significant.

3.5.2 SNARC effect

The interaction of Number Type×Response Hand was not significant by subjects but it was significant by items (see Table 2). For unitary singulars and plurals the interaction was consistent with the predicted SNARC effect. Responses for unitary singular nouns were faster with the left hand than with the right hand. The opposite was true for plural nouns. Collective singulars patterned with unitary singular nouns. The left-hand preference for collectives was numerically even bigger than for unitary nouns.

Table 4: Mean reaction times (ms) and accuracy (percent correct) for collective singular, unitary singular and plural nouns in the left-hand and right-hand response conditions in Experiment 1. Standard errors in parentheses.

NUMBER TYPE	RESPONSE HAND					
	Left		*Right*		*Congruity (Left-Right)*	
	RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT*	*Accuracy*
Collective Sng	853 (45)	80.60% (6.8)	906 (55)	78.00% (6.7)	-53	2.60%
Unitary Sng	774 (39)	97.70% (0.7)	787 (42)	97.40% (0.7)	-13	0.30%
Plural	820 (46)	97.50% (0.6)	791 (33)	97.30% (0.6)	29	0.20%

3.5.3 Size congruity effect

The Number Type×Font Size interaction was not significant either by subjects or by items (see Table 2). There was, therefore, no statistically valid evidence for any size congruity effect.

Table 5: Mean reaction times (ms) and accuracy (percent correct) for collective singular, unitary singular and plural nouns in the small-font and big-font conditions in Experiment 1. Standard errors in parentheses.

NUMBER TYPE	FONT SIZE					
	Small		*Big*		*Congruity (Small-Big)*	
	RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Collective Sng	882 (45)	78.90% (6.7)	877 (46)	79.70% (6.6)	5	-0.80%
Unitary Sng	778 (39)	98.00% (0.7)	783 (38)	97.20% (0.7)	-5	0.80%
Plural	812 (40)	97.30% (0.6)	798 (36)	97.50% (0.6)	14	-0.20%

3.6 Experiment 1 discussion

3.6.1 Plural interpretation of collectives

The accuracy data show that participants chose the “more than one thing” answer in 20.7% of responses in the collective singular condition, compared to just 2.4% in the unitary singular condition and 97.4% in the plural condition. This outcome is similar to the number judgment results for collectives in earlier studies with speakers of English (Bock & Eberhard, 1993) and Finnish (Nenonen & Niemi, 2010). Polish speakers participating in the experiment were aware that collective nouns can refer to multiple objects despite their grammatical singularity, although they were more likely to treat them as conceptually singular. A comparison of the reaction times within the collective singular condition showed that the “incorrect” (“more than one thing”) responses were slightly longer (1168 ms) than the “one thing” responses (951 ms), indicating that a plural construal for collectives required more time to compute, possibly as an effect of the need to override the initial singular interpretation.

3.6.2 SNARC effect

The interaction of the type of number (collective singular, unitary singular, plural) and the response side was significant, although only in a by-items analysis.

For unitary singular nouns participants responded significantly faster with the left hand than with the right hand, and the opposite was true for plural nouns. This pattern resembles the SNARC effect observed in many studies for small and large numbers (Dehaene et al., 1993; Gevers et al., 2006; Göbel et al., 2011) and replicates in Polish the findings for grammatical number in German (Röttger & Domahs, 2015). Apparently, Polish comprehenders in the experiment, like German users, automatically associated grammatically singular nouns with the left side of the mental space, while grammatically plural nouns were linked with the right side. This is consistent with the idea that processing grammatical number engages numerical representations arranged on a mental number line.

Collective singulars behaved like unitary singulars. This outcome is in line with the results from research on agreement attraction, where collective and non-collective singulars did not differ significantly (Bock et al., 2001a; Bock & Eberhard, 1993). It provides more support for the hypothesis that collective singulars are initially conceptualized as singular, with individual members highlighted only if contextually appropriate.

The fact that collectives in the present study seemed even "more singular" with respect to the SNARC effect than unitary nouns (the left-hand facilitation for collectives was numerically considerably larger than for unitary nouns) may have a morphological explanation. Most of the collective nouns used in the present experiment had an overt number-case ending (e.g., *grup-a* 'group-NOM.SG') in contrast to mostly zero-suffixed unitary singulars (e.g., *wilk-Ø* 'wolf-NOM.SG'). The presence of an overt ending on a noun may facilitate access to number information (this possibility was investigated in Experiment 3 and Experiment 4, presented in Chapter III and Chapter IV, respectively).

3.6.3 Size congruity effect

The interaction between the type of number and the visual size of the font was not significant. There was, therefore, no evidence that linguistic number can cause a size congruity effect. In particular, grammatical singularity and plurality did not activate small size and big size representations, respectively, despite giving rise to a SNARC effect. This result is surprising, given that a group of individuals is typically larger than a single individual of this category. Yet the group size does not seem to be part of the mental representation of number for language comprehenders. Perhaps this underrepresentation of size is due to the fact that plurals can easily refer to very small groups, possibly of just two individuals. The lack of a size congruity effect for grammatical number may also suggest that understanding the semantic contribution of grammatical number relies on the part of numerical cognition linking numerosities with spatial relations (hence the observed SNARC effect), but not with continuous magnitudes, like size.[19]

[19] The nature of the relations between continuous and discrete quantity processing systems is a matter of an ongoing debate. It is possible that a general magnitude processing mechanism exists where a common, modality-independent representation is assigned to all kinds of quantity. However, similarities in the processing of discrete and continuous quantities may also result from similar task demands or limitations of the basic cognitive systems,

It is also possible that the emergence of a size congruity effect was blocked by certain design features of Experiment 1. Experiment 2 tested this possibility.

4 Experiment 2

Experiment 1 showed no sign of a congruity effect of font size and number. The SNARC effect was present, but it was statistically significant only in a by-items analysis. The lack of a SCE and a statistically weak SNARC effect may be due to design choices, so another experiment was conducted, addressing some of the possible problems. Changes were introduced in four areas:

- Choice of task. The task used in Experiment 1 (semantic-number judgment: "Does the word name one or more than one thing?") was chosen to make the results comparable with past number judgment studies (Bock & Eberhard, 1993; Nenonen & Niemi, 2010) and to follow closely the design of Röttger & Domahs (2015), where a SNARC effect for grammatical number was demonstrated. However, by drawing the participants' attention to the number ambiguity of collectives, the semantic task may have been inappropriate for the present study. Experiment 2 addressed this problem by instructing participants to focus on the grammatical number instead (grammatical-number judgment: "Is this word singular or plural?").
- Selection of nouns for the collective singular condition. Whereas collective nouns for Experiment 1 were chosen based on the author's intuition, for Experiment 2 the sample was chosen in a pretest survey with a bigger group of Polish native speakers. Results of the survey were used to select grammatically singular nouns that most easily allow plural reference. The survey also helped to extend the number of collective lexemes to 30, equating them with the number of unitary lexemes.
- Choice of plural counterparts for collective singulars. In Experiment 1, instead of pluralizing collective singulars (e.g., *armie* 'armies' for *armia* 'army'), plural forms of

like working memory. For more information, see Henik et al. (2012), Van Opstal & Verguts (2013) or Walsh (2003).

related unitary nouns (e.g., *żołnierze* 'soldiers' for *armia* 'army') were used. While this was done to avoid a potential effect of number syncretism and "double plurality", it may have introduced more variance among items. In Experiment 2, proper plural forms were created from singular collectives.

- Matching item types. The words in Experiment 1 were not matched for frequency across conditions. Frequency has an effect on word recognition (Caramazza, Costa, Miozzo, & Bi, 2001; Forster & Chambers, 1973; Monsell, Doyle, & Haggard, 1989; Stephen Monsell, 1991; Rastle, 2007), so unequal frequency could be a confound. In Experiment 2, item types were better matched.

4.1 Method

The method remained the same as in Experiment 1 (SNARC and size congruity effect as number-meaning diagnostics).

4.2 Research question and predictions

As in Experiment 1, the research question concerned the primary numerical interpretation of collective singular nouns with respect to unitary singular and plural nouns. If collective singulars are linked with conceptual plurality already in the early stages of processing, they should pattern with plurals in terms of SNARC and, possibly, SCE. If the plurality of collectives is computed later, after the initial activation of conceptual singularity (driven by the grammatical number), they should behave more like unitary singulars. If both readings are automatically activated early on (competing for selection) the results for collective singulars should fall somewhere between unitary singulars and plurals.

4.3 Design

4.3.1 Materials

A pretest was organized to select nouns whose collective reading is most salient. A questionnaire with a list of words was presented to participants, who evaluated how often every word is used to refer to more than one entity. Participants made their decision on a scale from 1 (very rarely) to 5 (very often). The list contained 188 words of which 62 were singular nouns with a potentially collective reading (e.g., *ekipa* 'squad'). The remaining words were unitary singulars (e.g., *wilk* 'wolf'), *pluralia tantum* (e.g., *nożyce* 'scissors'), mass nouns (e.g., *błoto* 'mud') and ordinary plurals (e.g., *drzewa* 'trees'). The questionnaire was distributed online through Google documents. Ten native speakers of Polish took part. Responses for each item were averaged over all participants. Full results of the pretest are available in Appendix 2. Thirty collective nouns with the highest scores were selected for the experiment. Of the selected nouns, the lowest rated item (*sztab* 'military headquarters') received 3.6 points and the highest rated (*trzoda* 'lifestock') received 4.7 points (M=4.22 SD=0.27).

In addition to the 30 collective singular nouns, 30 unitary singular nouns were selected. Plural forms were created from all singulars. The items formed four groups (collective singular, unitary singular, collective plural, unitary plural), matched as closely as possible for the mean number of letters and surface frequency, based on the information from the National Corpus of Polish (Przepiórkowski et al., 2012) using the PELCRA system (Pęzik, 2012) (see Table 6). ANOVA tests showed that the differences were insignificant for both the number of letters ($F(3,119)=2.11$ $p=.102$) and frequency ($F(3,119)=0.01$ $p=.998$).

Table 6: Mean letter lengths and surface frequencies (per million) for different item types used in Experiment 2 (standard deviations in parentheses).

	LETTERS	FREQUENCY
SINGULAR COLLECTIVE	5.67 (0.92)	15.40 (29.54)
SINGULAR UNITARY	5.37 (0.96)	15.70 (23.52)
PLURAL COLLECTIVE	6.00 (0.87)	14.85 (29.75)
PLURAL UNITARY	5.73 (1.14)	14.77 (19.01)

Overall there were 60 singular and 60 plural nouns. Each noun was presented in big font and small font as well as with a left-hand and right-hand response. Every participant saw all items. This resulted in 480 trials distributed over two blocks. The presentation order was fully randomized for every participant.

4.3.2 Procedure

Experiment 2 was conducted on the same standard PC computer and the 23.6 inch monitor as Experiment 1.

The design was mostly the same as in Experiment 1, except for the task. This time the participants were instructed to determine whether the noun is grammatically singular or plural (a grammatical-number judgment task) while ignoring the visual size of the stimulus. The font sizes in the two size conditions and the resulting visual angles for stimuli were the same as in the previous experiment.

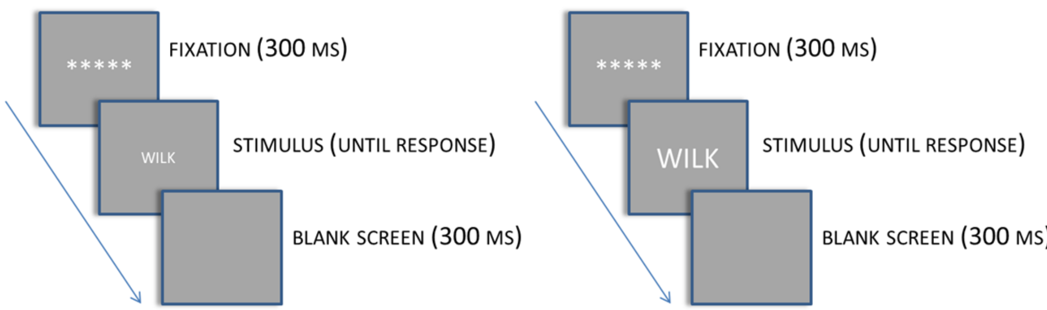

Figure 7: The structure of a trial in Experiment 2 in the small font and big font condition.

Experiment 2 again consisted of two blocks, with the assignment of keys to responses changing after the first block. There were three breaks within each block (every 60 trials). In each block, the experiment proper was preceded by a training session with 22 trials. The set of training items consisted of nouns balanced in terms of grammatical number, font size and response hand. None of the items used in the training session appeared later in the experiment proper. During the training session, a 1000 ms feedback was provided informing the participant whether the answer was correct or incorrect. During the experiment proper, feedback was provided only for incorrect responses.

The experiment was designed and presented using the PsychoPy software (version 1.84.2) (Peirce, 2007, 2009).

4.3.3 Participants

Twenty-three students of the Institute for English Studies of the University of Wrocław (8 men) took part in the experiment. Participants were all native speakers of Polish. The average age was 22.4 (*SD*=5.5).

4.4 Results: Accuracy

In Experiment 2, participants were required to focus on the grammatical number of words and decide whether each noun is singular or plural. The accuracy measure, therefore, did not reflect the numerical interpretation of the stimuli. This time the differences between the types of number were very small. Participants were on average most accurate with unitary singular nouns (*M*=98.5% *SE*=0.6) and slightly less accurate with collective singulars (*M*=97.3% *SE*=0.6) and plurals (*M*=97% *SE*=0.4). A one-way ANOVA with Accuracy as the dependent variable and Number Type (collective singular, unitary singular, plural) as the independent factor showed that these differences were significant by subjects ($F_1(2,44)=5.46$ $p=.008$ $\eta^2=.20$) but not by items ($F_2(2,117)=1.34$ $p=.27$).

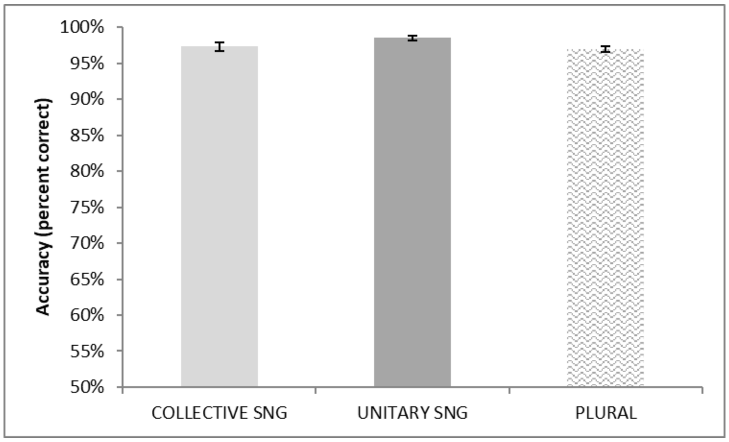

Figure 8: Average accuracy (percent correct) for collective singular, unitary singular and plural nouns in Experiment 2. Bars represent standard errors.

4.5 Results: Reaction times

The data were cleaned first by removing all incorrect responses. After that, all trials with reaction times (RT) 3 standard deviations above and below the mean for every participant were removed. This resulted in eliminating 215 data points which constituted 2% of correct responses. The remaining trials were subjected to tests performed with the SPSS software (version 22).

In order to test the research hypotheses, a 3×2×2 ANOVA was conducted with RT as the dependent variable and the following independent factors:

- Number Type (collective singular, unitary singular, plural)
- Font Size (small, big)
- Response Hand (left, right)

Results of the ANOVA test are given in Table 7. Mean response times and accuracy in each condition are given in Table 8.

Table 7: ANOVA test results for Experiment 2.

Source	*df*		*F*		*p*		Partial Eta Sq.	
	SUBJECTS	ITEMS	SUBJECTS	ITEMS	SUBJECTS	ITEMS	SUBJECTS	ITEMS
NUM. TYPE	2, 44	2, 117	20.31	9.82	0.000*	0.000*	0.48	0.14
FONT SIZE	1, 22	1, 117	0.02	0.06	0.893	0.815	0.00	0.00
RESP. HAND	1, 22	1, 117	0.47	1.17	0.499	0.281	0.02	0.01
NUM. TYPE× FONT SIZE	2, 44	2, 117	2.57	1.03	0.088	0.361	0.11	0.02
NUM. TYPE× RESP. HAND	2, 44	2, 117	0.07	0.22	0.932	0.803	0.00	0.00
FONT SIZE× RESP. HAND	1, 22	1, 117	2.35	1.16	0.140	0.283	0.10	0.01
NUM. TYPE× FONT SIZE× RESP. HAND	2, 44	2, 117	2.86	1.55	0.068	0.216	0.12	0.03

Table 8: Mean reaction times (ms) and accuracy (percent correct) in all conditions in Experiment 2. Standard errors in parentheses.

NUMBER TYPE	FONT SIZE	RESPONSE HAND					
		Left		*Right*		*Congruity (Left-Right)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Collective Sng	*Small*	830 (34)	96.2% (1.1)	834 (39)	97.4% (7.0)	-4	-1.2%
	Big	818 (31)	97.1% (7.0)	830 (36)	98.6% (6.0)	-12	-1.5%
Unitary Sng	*Small*	765 (27)	98.8% (4.0)	743 (24)	98.7% (4.0)	22	0.1%
	Big	755 (26)	98.1% (5.0)	776 (28)	98.3% (5.0)	-21	-0.2%
Plural	*Small*	794 (31)	97.0% (4.0)	808 (30)	97.5% (6.0)	-14	-0.5%
	Big	798 (32)	96.4% (5.0)	802 (30)	97.0% (4.0)	-4	-0.6%

4.5.1 Number type effect

The main effect of Number Type was significant (see Table 7). Responses to collective singular nouns were on average longest (*M*=828 ms *SE*=33), followed by responses to plural nouns (*M*=801 ms *SE*=29) and to unitary singular nouns (*M*=760 ms *SE*=24).

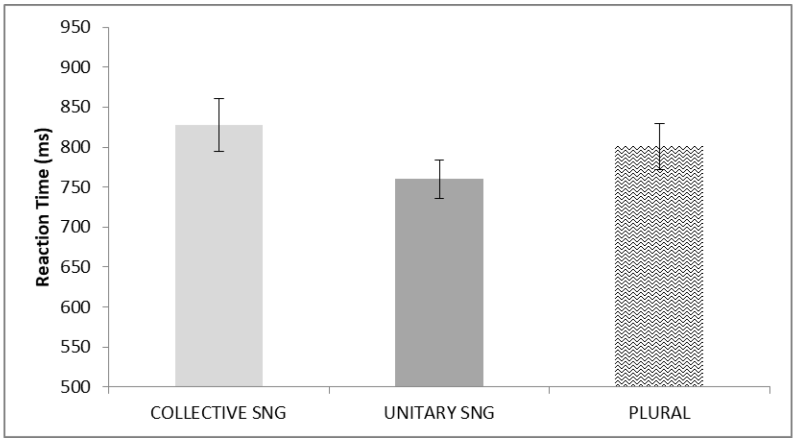

Figure 9: Reaction times (ms) for collective singular, unitary singular and plural nouns in Experiment 2. Bars indicate standard errors.

No other main effect was significant.

4.5.2 SNARC effect

The interaction of Number Type×Response Hand was not significant either by subjects or by items (see Table 7). There was no statistically valid evidence for a SNARC effect.

4.5.3 Size congruity effect

The Number Type×Font Size interaction was not significant either by subjects or by items (see Table 7). There was no statistically valid evidence for a size congruity effect.

4.6 Experiment 2 discussion

Experiment 2 was conducted as an attempt to elicit a size congruity effect for grammatical number and lexical collectivity, which was absent in Experiment 1. The results once again showed no size congruity effect. Moreover, the SNARC effect present in Experiment 1 was also absent from the Experiment 2 data. One of the main changes in Experiment 2 with respect to Experiment 1 was a change in the task. The semantic-number judgment task ("Does the word name one or more than one thing?") from Experiment 1 was replaced by a grammatical-number judgment task ("Is this word singular or plural?"). The change was intended to turn the participants' attention away from the number ambiguity of collective singulars while keeping the task in the domain of number. However, in Experiment 2 conceptual number was apparently not extracted fast enough to affect the performance and produce a SNARC effect. As discussed in Section 6.2 of Chapter I, Röttger & Domahs (2015) found a SNARC effect for German singular and plural nouns only for the task requiring the processing of semantic number but not for tasks related to other types of information (animacy semantics, lexical status, visual features). This outcome, together with the lack of significant results for Experiment 2, shows that the SNARC effect may be particularly sensitive to the type of task.

5 General discussion (Experiment 1 and Experiment 2)

Experiment 1 (semantic-number judgments) managed to replicate the SNARC effect reported previously for grammatical number in Röttger & Domahs (2015), albeit in a weak form (it was statistically significant only by items). This confirms the suitability of SNARC as a tool for studying the conceptual representation of number in language. Experiment 2 (grammatical-number judgments), on the other hand, failed to produce any SNARC effect, which points to a task-sensitive nature of this effect.

Neither Experiment 1 nor Experiment 2 provided any evidence that the conceptual representation of number in language can lead to a size congruity effect. This null result may indicate the limits of mental simulations based on linguistic information (Barsalou, 1999; Zwaan, 2009). It seems that the size of the denoted set is not a well-defined property of the conceptual representation of linguistic number. It is possible that the size of the average member of a group is more salient than the size of the group itself (see the work of Paivio (1975), discussed briefly in Section 6.3 of Chapter I). The nouns used in the two experiments were not matched for average sizes of the denoted individuals (the items included, for example, words like *pasek* ‘belt’ and *stół* ‘table’). Perhaps a more careful choice of items is necessary to detect a size-congruity effect related to grammatical number or collectivity.

The main research question concerned a direct comparison of collective singulars (words with a conflict between the grammatical and lexical number), on the one hand, with unitary singular and plural nouns, on the other. Polish native speakers participating in the experiments were aware of the possible plural (“more than one thing”) reading of collective singulars, as indicated by their accuracy in Experiment 1 and the answers in the pretest questionnaire conducted before Experiment 2 (see Appendix 2). Collective singulars could, therefore, be expected to be conceptually similar to plural nouns. However, in Experiment 1 collective singular nouns behaved like unitary singular nouns and differed from plural nouns in terms of the SNARC effect. Plural nouns received faster responses with the right hand than with the left hand. In contrast, collective and unitary singulars showed a clear preference for the left hand (the preference for collectives was even bigger than for unitary singulars). This matches the hypothesis that the reference of a collective noun is initially construed as a single entity (the whole group), consistent with the grammatical singularity of the word, and the plural interpretation could be the result of a pragmatic highlighting of component parts rather than being automatically activated as soon as the noun is encountered and recognized. Moreover, the “more than one thing” responses for collective singulars were longer than the “one thing” responses, providing additional evidence that the plural interpretation likely originated at later stages of lexical analysis and had to suppress the earlier automatic activation of the conceptual singularity computed on the basis of the grammatical number.

The SNARC effect results of Experiment 1 are consistent with past research on number agreement, where collective singular nouns did not lead to agreement attraction in contrast to a robust attraction from grammatically plural nouns (Bock & Eberhard, 1993, Experiment 4; Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001, Experiment 3). It should also be pointed out that the variance in the semantic-number judgments for collective singulars in Experiment 1 was relatively high. The “one thing” responses for collectives varied from 74% for *armia* ‘army’ and *brygada* ‘brigade’ to 88% for *zbiór* ‘set’. A high variance for collectives has been reported before by Nenonen & Niemi (2010).

CHAPTER III

MORPHOLOGICAL MARKEDNESS[20]

1 Introduction and chapter overview

Processing grammatical number requires usually a successful mapping from number forms to number concepts.[21] Natural languages use a variety of devices to express number values (see, Section 2.1 and Section 2.2 of Chapter I for an overview). In terms of number expression forms there seems to be a marking asymmetry: if a language distinguishes singular and plural number, the plural value tends to be morphosyntactically marked, while the singular value can be expressed through unmarked forms.[22] For example, in reduplication languages it is the plural form that is completely or partially repeated, like in Indonesian (e.g., *rumah* 'house' vs. *rumah-rumah* 'houses') or in the Uto-Aztecan language Pipil (e.g., *rayis* 'root' vs. *rah-rayis*). In suffixing languages, the plural form receives an ending, which the singular form lacks (e.g., *Frau* 'woman' vs. *Frauen* 'women' in German). Greenberg put this observation on the list of

[20] The experiment presented in this chapter is also described in Gulgowski & Błaszczak (2018).

[21] The situation is more complex for nouns with a conflict between grammatical and lexical number or nouns whose numerical reading is influenced by other elements in the sentence, as discussed in the present thesis.

[22] The concept of markedness is rooted in the theory of oppositions developed by, among others, Jakobson (1957).

his language universals: "There is no language in which the plural does not have some nonzero allomorphs, whereas there are languages in which the singular is expressed only by zero" (Greenberg, 1963, Universal 35).[23] From a psycholinguistic perspective, an interesting question in this context is whether the presence or absence of an overt number marker affects the processing of grammatical number information.

Evidence for an asymmetry between the treatment of singularity and plurality in language processing has been uncovered by some psycholinguistic studies (Berent et al., 2005; Bock & Miller, 1991; Pearlmutter et al., 1999). However, previous research focused mostly on languages like English, German or Dutch, that is languages in which virtually all singular forms are unmarked and most plural forms have an overt number suffix. It is unclear whether the observed processing differences were caused by the contrast in morphological marking or by the fact that one of the number values is inherently easier to process than the other. In Polish, on the other hand, with its complex case/number marking system (see Section 2.4 of Chapter I), unmarked singular forms (e.g., *kot-Ø* 'cat-NOM.SG') exist alongside morphologically marked singulars (e.g., *lamp-a* 'lamp-NOM.SG'). This allows for a direct comparison of plural forms (always marked) with both marked and unmarked singulars. To check what effect the (un)markedness in terms of form may have on the processing of grammatical number, Experiment 3 used the numerical Stroop interference technique as a diagnostic for which numerical concepts are extracted automatically from numbered forms.

The present chapter provides an overview of past research revealing a processing asymmetry for singular and plural nous as well as some evidence that the asymmetry can be removed by making the singular form marked. This is followed by a presentation of the method chosen for

[23] This typological pattern has been used as an argument in the debate about the proper account of number semantics. For example, Farkas & de Swart (2010), following "Horn's division of pragmatic labor" (Horn, 2001) argue that plurals, being morphologically marked, have a specific number meaning (they refer to a group of objects), while singulars are neutral with respect to number interpretation, which is consistent with their frequent use in generic constructions (e.g., *bird watcher*, *prize winner*). Other scholars proposed that the opposite situation is true. Sauerland et al. (2005) present their "weak theory" of the plural. According to this approach, singular nouns are associated with a stronger presupposition (the referent must be a single atomic entity), in comparison with plural nouns (accepting both single and multiple referents). The pragmatic principle of Maximize Presupposition (originally proposed by Heim, 1991) rules that a plural form can be used only if the stronger presupposition of a singular form is not satisfied in a given context. This brief overview only scratches the surface of the ongoing debate among theoretical semanticians. However, it is not an ambition of this thesis to contribute to formal analyses of number semantics. The focus here is instead on the cognitive representations of number concepts.

the experiment and the specific research questions, hypotheses and predictions. Next, the description of the experimental design (with materials and procedure), data analysis and results are presented. The chapter ends with the summary and discussion.

2 Background: Markedness in the processing of grammatical number

Some evidence for a processing asymmetry between (marked) plural and (unmarked) singular number has been provided by research on agreement attraction (see Section 4.2 of Chapter I and Section 2 of Chapter II). A plural attractor (e.g., *The key to the* *cabinets*…) is more likely to produce agreement errors than a singular attractor (e.g., *The keys to the* *cabinet*…).[24] This asymmetry has been found in multiple studies (Bock & Miller, 1991; Lorimor et al., 2008; Pearlmutter et al., 1999). According to a markedness account developed in Bock & Eberhard (1993) and Eberhard (1997), plural forms possess a specific number feature, while singular forms are not specified in this way. Establishing subject-verb agreement involves a search for the number feature of the subject. If a feature is found, the verb receives plural agreement morphology, otherwise it receives (default) singular agreement. Intervening plural attractors introduce a number feature that can erroneously trigger plural agreement despite a singular subject. Intervening singular nouns do not interfere with the agreement process, because they lack a positive feature of their own. This account predicts that if a normally unmarked singular noun were to receive a specific singular number feature through overt means, the pattern of typically observed agreement errors would change. This possibility was investigated in Eberhard (1997), where singular English nouns were preceded either by a quantifier that requires a singular noun (*one*, *each* or *every*) or by the definite article. The singular-requiring quantifiers can function as reliable markers of singularity. In contrast, the definite article can be used with both plural and singular nouns, so it does not reliably mark number. Following this logic, singulars were considered marked if preceded by a quantifier (e.g., *one/each/every*

[24] For an overview and discussion see Häussler (2012, especially pp. 70-72).

key) and unmarked if preceded by the determiner (e.g., *the key*). Participants were asked to complete sentence fragments containing noun phrases. In one experiment, marked and unmarked singular nouns functioned as sentence subjects (e.g., *The/One key to the cabinets…*). Results showed that marked singular nouns used as subjects were more resistant to agreement attraction from intervening plural elements in comparison to unmarked singular nouns. The author interpreted the result as evidence that a singular noun overtly marked by a quantifier was able to transmit a number feature to the verb for the purpose of agreement, in contrast to unmarked singulars, where such transmission did not occur (or was less efficient). In another experiment of the same study, singular noun phrases functioned as possible attractors (e.g., *The keys to the/one cabinet…*). Marked singular attractors generated more agreement errors than unmarked singulars. A comparison of both experiments, however, showed that the agreement attraction from singular nouns (even when they are marked) is considerably weaker than the attraction from plural nouns. This suggests that, although singular nouns in English can be marked through non-morphological means, i.e., through singular-compatible quantifiers, the resulting number specification is not as strong as the one stemming from a plural suffix. In English, the overwhelming majority of singular nouns are unmarked morphologically (possible exceptions are loanwords, like *alumnus* or *forum*, although it is debatable whether English speakers recognize the *-us* or *-um* endings as singular morphemes). Using a singular-requiring quantifier constitutes a non-grammatical, periphrastic way of marking singularity.

What about languages where singular nouns have an overt grammatical number suffix? Vigliocco, Butterworth, & Semenza (1995) conducted sentence-completion experiments to investigate agreement attraction in Italian. Italian is a language with a richer inflectional system than English. Italian nouns have overt number/gender endings also for singulars. In the first two experiments of this study, the number morphology on attractor nouns was not controlled. A full list of materials is unavailable, but based on the few example stimuli provided in the paper, it can be assumed that at least some attractors were marked for singularity (e.g., *Il gatto sui tetti/tetto…* 'The cat on the roofs/roof…'; *La città sulle colline/collina…* 'The town on the hills/hill…'). In this context, it is worth noting that in the first experiment (stimuli presented auditorily), the number of agreement errors found for plural attractors (n=27) was almost the same as for singular attractors (n=29). In the second experiment (stimuli presented visually, responses cued by an adjective), the number of errors after singular attractors (n=59) was significantly lower than the number of errors after plural attractors (n=116). The singular/plural asymmetry was, therefore, present for visual modality, although the proportion of agreement errors after singular and plural attractors was relatively high in contrast to the English data from Bock & Miller (1991).[25] The type of morphological number marking on attractor nouns was manipulated in the third experiment (stimuli presented auditorily). Some nouns, called marked in the paper, had distinct endings in the singular and plural form (e.g., *La scoperta dello scienzato/degli scienzati*… 'The discovery of the scientist/the scientists…'), whereas others, called invariant, did not differ in form between numbers (e.g., *La trama del film/dei film*… 'The plot of the film/the films…'; *Il bar nella città/nelle città*… 'The bar in the town/the towns'). The grammatical number of the whole noun phrase was always unambiguously indicated by articles. The results showed that there was no statistically significant effect of morphological marking on attractors. The number of agreement errors following marked singular attractors (n=11) was almost identical to the number of errors following invariant singular attractors (n=10). Plural attractors again gave rise to more agreement errors than singulars (n=17 and n=23 for marked and invariant plurals, respectively). Manipulating number morphology did not change agreement attraction in this experiment. Overall, the results are mixed. Singular nouns in Italian (a language that generally uses overt singularity markers) seem more likely to produce agreement attraction than singulars in English. On the other hand, marked singulars in Italian did not attract agreement more than unmarked singulars in a direct comparison.[26]

To sum up the findings of past agreement studies, morphologically unmarked singular nouns (at least in English) do not give rise to agreement attraction errors unless they are marked through non-morphological means (e.g., by a quantifier requiring a singular noun), and even then the attraction is weaker than for (marked) plurals. In languages with overt singular morphology (like Italian), the asymmetry may be less pronounced, with singulars more likely

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[25] In Experiment 1 (auditory modality) of Bock & Miller (1991), there were 50 agreement errors in unambiguous sentence completions after plural attractors vs. just 7 following singular attractors.

[26] Both marked and invariant nouns in Vigliocco, Butterworth, & Semenza (1995) could have an overt ending in the singular form, so the notion of markedness used in that paper and the one used in the present thesis are somewhat different.

to produce agreement attraction errors. It is not clear, however, to what extent subject-verb agreement is sensitive to number semantics. For this reason, the results of agreement studies cannot be used to form decisive conclusions about the relation between morphosyntactic markedness and the conceptual representation of number.

Works not based on agreement phenomena are less common. A numerical Stroop experiment with singular and plural Hebrew words conducted by Berent et al. (2005) (see Section 6.1 of Chapter I) offers some insight in this regard. An interference between visual numerosity and grammatical number was obtained in this study only for grammatically plural words, i.e., subjects took longer to decide how many words they see on the screen when a word with a plural suffix was presented as a single token (e.g., *dogs*) than when it was presented as two tokens (e.g., *dogs dogs*). Singulars did not differ significantly from the control (meaningless strings of repeated letters).

Polish offers an interesting research opportunity in this area because of the characteristics of its inflectional system. While some Polish nouns have no suffix in the nominative singular form (e.g., *kot-Ø* 'cat-NOM.SG'), others have an overt nominative singular ending (e.g., *małp-a* 'monkey-NOM.SG'). Lorimor et al. (2008) found a singular-plural asymmetry in agreement attraction for Russian, another Slavic language with many similarities to Polish. Russian participants made more verb agreement errors in a sentence completion task when the subject was singular and the distractor plural than in the opposite condition (although the overall effect was considerably weaker than for comparable English studies, suggesting less vulnerability to attraction disruption in Russian). However, the authors did not control for the type of morphological marking. Contrasting morphologically marked and unmarked singular nouns with each other and with plural nouns should reveal the effect of morphological markedness on the processing of grammatical number. This can be accomplished using the numerical Stroop-interference technique.

3 Experiment 3

3.1 Method

The technique from Experiment 1 and Experiment 2, involving the SNARC effect and the size congruity effect, brought mixed results. No SCE was found for either grammatical or lexical number and the obtained SNARC effect was very weak. Because of possible methodological problems, the SNARC-SCE technique was not used in any other experiment presented in this thesis. The method selected for Experiment 3 and the remaining experiments was the numerical Stroop effect. As already discussed in Chapter I (Section 6.1), the most well-known type of a Stroop effect consists of difficulties with naming the font color of a word when it is incongruent with its meaning, for example, when the word *red* is written in green font. A kind of Stroop effect exists also for representations of numbers. It has been demonstrated that counting instances of number words or digits presented visually takes more time when the visual numerosity is incongruent with the numerical value (e.g., symbol *2* repeated four times: *2 2 2 2*) than in congruent or control conditions (Flowers, Warner & Polansky 1979; Naparstek & Henik 2010; Pavese & Umiltà 1998; Windes 1968). A numerical Stroop effect was found for grammatical number in Hebrew by Berent et al. (2005) and in English by Patson & Warren (2010). The technique has been chosen for the present experiment because of its sensitivity to number concepts and relation to fast and automatic processes reflected in response times during a word counting task.

3.2 Research question and predictions

The main hypothesis tested in Experiment 3 was that the ease of activating numerical concepts associated with grammatical number depends on the presence or absence of an overt number marker. The varying strength of numerical concepts are expected to be reflected in the numerical Stroop interference for marked and unmarked nouns. A strong congruity effect between grammatical number and visual numerosity could be expected for all plurals used in the experiment, because they were marked with an overt number ending. Participants should be faster to count plural nouns when two tokens are displayed on the screen than when only one token is presented. An opposite congruity effect was expected for singular nouns marked with a suffix. That is, participants should count marked singulars faster in the visually single than in the visually double condition. Unmarked singulars should differ from both plural nouns and singular nouns with a suffix – they should not give rise to any number congruity effect, or the effect should be significantly weaker than for marked singulars.

3.3 Design

3.3.1 Materials

One hundred Polish nouns were used in the experiment, all in nominative case:

- 50 singular nouns
    - 25 unmarked singulars (e.g., *czołg-Ø* 'tank-NOM.SG')
    - 25 marked singulars (e.g., *lekcj-a* 'lesson-NOM.SG')
- 50 marked plural nouns created from the same stems as the singulars (e.g., *czołg-i* 'tank-NOM.PL', *lekcj-e* 'lesson-NOM.PL')

Case syncretism is quite common in Polish declensional paradigms and some forms can be ambiguous not only in terms of their case but also their number value (cf. *mysz-y* 'mouse-NOM.PL' or 'mouse-GEN.SG'). No word picked for this experiment was number ambiguous in this way.

Additionally, following the design in Berent et al. (2005), 40 strings of repeated letters (e.g., *aaaaaa*) were created. Ten different letters of the Polish alphabet of comparable width (*a, b, c, d, e, g, h, u, o, y*) were used, each appearing in four strings: two 5-letter and two 6-letter strings. Repeated letters were used to guarantee that no number-related semantic interpretation could be associated with those items.

Item types were matched for the number of letters and surface frequency based on the information from Narodowy Korpus Języka Polskiego (Przepiórkowski, Bańko, Górski &

Lewandowska-Tomaszczyk, 2012) using the PELCRA system (Pęzik, 2012). Plural nouns were on average slightly longer and less frequent than singulars (see Table 9). A one-way ANOVA for Item Type (unmarked singulars, marked singulars and plurals) with Letters as the dependent variable showed the difference was statistically significant (F=3.61 p=.030). A similar ANOVA with Frequency as the dependent variable was not significant (F=0.52 p=.600).

Table 9: Mean letter lengths and surface frequencies (per million) for different item types used in Experiment 3 (SDs in parentheses).

	Letters	Frequency
Unmarked Singular	5.12 (0.67)	5.20 (4.42)
Marked Singular	5.16 (0.90)	5.20 (4.62)
Marked Plural	5.64 (0.92)	4.10 (5.26)
Neutral Strings	5.50 (0.50)	NA

There were 140 items in total. Each item appeared both as a single token (e.g., *lekcja*) or repeated twice (e.g., *lekcja lekcja*). Therefore the total number of trials in the experiment was 280. The order of items was pseudo-randomized and two lists were created before the experiment, one being the exact inverted image of the other. Half of the participants saw one list and the remaining half saw the other list.

3.3.2 Procedure

The experiment started with a greeting message and instructions displayed on the screen. The message explained that the task of the participant was to count the number of words (e.g., *lekcja* 'lesson') or letter strings (e.g., *aaaaaa*) appearing on the screen by pressing the left arrow key when the item was visible as a single token (e.g., *aaaaaa*) or the right arrow key when the item appeared on the screen twice (e.g., *aaaaaa aaaaaa*).

Each trial started with a fixation cross in the middle of the screen. The cross remained visible for 300 ms and was followed by 300 ms of blank screen and then either a single token of an experimental item or an item repeated twice appeared. The item(s) remained on the screen until the participant reacted by pressing the left or the right arrow. If the response was incorrect, there was a 400 ms feedback informing the participant about the mistake. If the reaction was correct, there was no feedback. In every case the trial ended with 300 ms of a blank screen before the next trial began. See Figure 10 for the visual representation of the structure of a trial.

The experiment proper was preceded by a training session that followed the same procedure with the exception that a feedback was given for both incorrect and correct responses. There were 10 training trials using number-neutral words, e.g., *wolno* 'slowly'. The training ended with a message informing about the number of correct and incorrect responses, encouraging the participant to ask questions and informing about the possibility of repeating the session. No training item appeared later in the experiment proper.

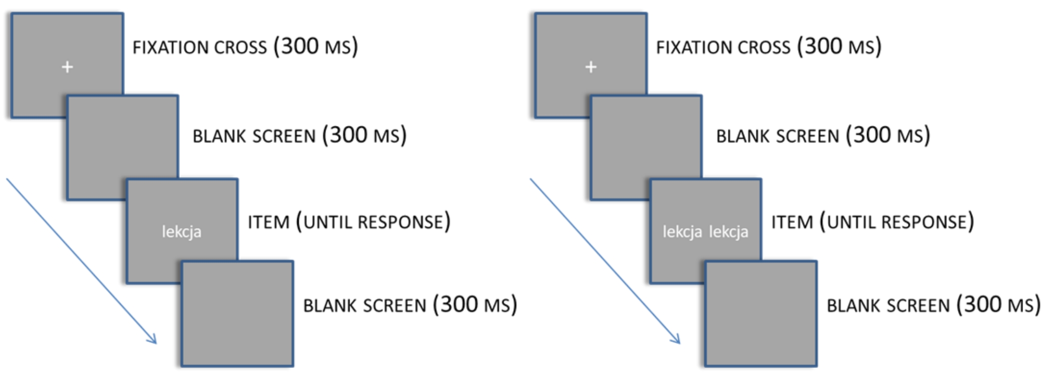


Figure 10: The structure of a trial in Experiment 3 in the visually single and visually double condition.

Halfway through the experiment there was a message informing about a break. The participants could proceed when ready by pressing the space bar. Each experiment session lasted approximately 10-15 minutes. The experiment was designed and presented using the PsychoPy software (version 1.84.2) (Peirce 2007; 2009).

3.3.3 Participants

Thirty-one students of the Institute for English Studies of the University of Wrocław (20 women) took part in the experiment. Participants were all native speakers of Polish. The average age was 20 (*SD*=2.13). Data from one participant had to be removed from the final analysis due to low overall accuracy (<75%).

3.4 Results: Reaction Times

The data were cleaned first by removing incorrect responses and then by eliminating the trials with reaction times (RT) 2 standard deviations above or below the mean in each condition for every participant. This resulted in removing 5% of accurate responses. The remaining trials were subjected to tests performed with the SPSS software (Version 22).[27] Mean RT and accuracy are given in Table 10.

Table 10: Mean reaction times and accuracy (percent correct) for different item types in Experiment 3 displayed as visually single or double (standard errors in parentheses).

Item Type		Visual Number					
		Visual 1		*Visual 2*		*Congruity (Visual 1-Visual 2)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Unmarked Singular	*tygrys* 'tiger'	490 (12)	98.7%	493 (14)	97.6%	-3	1.1%
Marked Singular	*wieża* 'tower'	494 (13)	98.9%	505 (16)	97.9%	-11	1%
Marked Plural	*tygrysy* 'tigers'	494 (13)	98.0%	488 (14)	97.2%	6	0.8%
Neutral Strings	*yyyyyy*	504 (13)	97.3%	483 (14)	97%	21	0.3%

A **3×2 ANOVA** was conducted with RT as the dependent variable and the following independent factors:

- Item Type (unmarked singular, marked singular, marked plural)
- Visual Number (visual 1, visual 2)

There was no significant main effect of either Item Type ($F_1(1.92,55.58)=2.95$ $p=.060$; $F_2(2,97)=2.72$ $p=.073$) or Visual Number ($F_1(1,29)=0.34$ $p=.561$; $F_2(1,97)=0.67$ $p=.420$).

The interaction between the two factors was significant by subjects ($F_1(1.83,53.19)=3.48$ $p=.042$ $\eta_p^2=.11$) but not by items ($F_2(2,97)=2.23$ $p=.114$). An examination of the data revealed

[27] The number-neutral condition (meaningless strings of letters, e.g., *zzzzzz*), contrary to the expectations, produced the greatest difference between the two visual number conditions. Strings of repeated letters turned out to be considerably faster to count when two tokens were displayed on the screen than when they appeared as one token (see Table 10). This, notably, was not the case in the original experiment by Berent et al. (2005). This result makes the strings in the present experiment problematic as a baseline condition. For this reason, strings of repeated letters were excluded from the analysis.

the presence of a congruity effect: singular nouns of both types were responded to faster in the visually single condition than in the visually double condition. The pattern was reversed for plural nouns. To further analyze the nature of this interaction and test the research hypotheses, planned comparisons were computed.

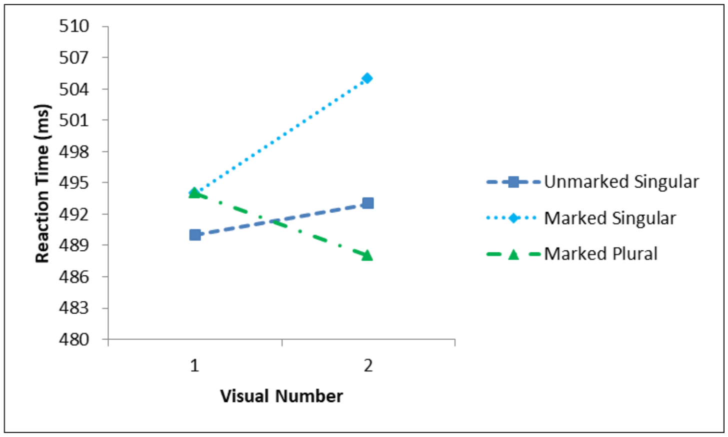


Figure 11: The interaction of Item Type and Visual Number in Experiment 3.

The first set of comparisons checked the possible Item Type×Visual Number interactions for individual pairs of item types (Table 11). For unmarked singular nouns compared to marked singular nouns the interaction was not statistically significant. It was also not significant for unmarked singulars compared to plurals or for all singulars put together compared to plurals. However, it reached the level of significance (by subjects) for marked singular nouns compared to plurals, indicating that those two item types generated most difference in congruity effects.

Table 11: Results of planned comparisons testing Item Type×Visual Number interactions for individual pairs of item types in Experiment 3 (p-values adjusted: Sidak method).

Comparison (Visual 1 vs. Visual 2)	*df*		*t*		*p*	
	Subjects	Items	Subjects	Items	Subjects	Items
Marked Singular vs. Marked Plural	58	97	2.64	2.08	.043*	.150
Unmarked Singular vs. Marked Plural	58	97	1.38	1.03	.531	.774
Unmarked Singular vs. Marked Singular	58	97	-1.251	-0.91	.623	.844
Singular (all) vs. Marked Plural	58	97	-2.320	-1.91	.090	.220

Another set of comparisons involved checking whether the congruity effect (the difference between average RT in the visual 1 and visual 2 conditions) is significant for individual item types: marked plurals, marked and unmarked singulars and all singulars taken together (Table 12). None of the comparisons reached the level of statistical significance.

Table 12: Results of planned comparisons testing the significance of the congruity effect for individual item types in Experiment 3 (p-values adjusted: Sidak method).

COMPARISON (VISUAL 1 VS. VISUAL 2)	*df*		*t*		*p*	
	SUBJECTS	ITEMS	SUBJECTS	ITEMS	SUBJECTS	ITEMS
MARKED PLURAL	55.61	97	0.81	1.19	.890	.661
MARKED SINGULAR	55.61	97	-1.74	-1.71	.314	.322
UNMARKED SINGULAR	55.61	97	-0.53	-0.42	.974	.990
SINGULAR (ALL)	35.73	97	-1.29	-1.51	.601	.443

4 Discussion

Experiment 3 managed to replicate in Polish the numerical Stroop effect reported by Berent et al. (2005) for grammatical number in Hebrew. As predicted, the process of counting nouns displayed on the screen as one or two tokens was affected by the grammatical number of the counted words. For grammatically plural nouns, participants took longer to decide that the word was presented as one token on the screen than to decide that two tokens were displayed. For singular nouns, the opposite was true.

Singular nouns used in the experiment belonged to two different types: those encoding singular number through an overt suffix (marked) and those with no number ending (unmarked). Morphologically marked singulars produced a bigger congruity effect than unmarked singulars. Only marked singulars differed in terms of congruity effect from plurals. The data offer, therefore, some support for the main hypothesis: the ease of extracting number information from a noun (as indicated by the strength of the numerical Stroop interference between grammatical number and visual numerosity) depends on the presence of an overt morphological marker. It has to be noted that the overall effect of visual number manipulation was very weak.

In Berent et al.'s (2005) numerical Stroop study, grammatically singular nouns did not produce any interference with visual number in the counting task. The outcome of Experiment 3 suggests that singular nouns are more likely to evoke a specific numerical concept ("exactly one") if they are clearly marked morphologically. The presence of an overt marking may provide an important cue for the parser facilitating the extraction of the number value from the word in contrast to an unmarked singular noun. It is possible that an unmarked singular noun is temporarily perceived as a pure numberless stem requiring an ending. While this form is obviously eventually recognized as a singular noun, the delayed activation of the concept of number might reduce its interaction with the visual number of tokens on the screen in the counting task.

One unexpected outcome of the present experiment raised a methodological issue for future numerical Stroop effect studies. Number-neutral strings produced the strongest difference between the visually single and visually double conditions (see Table 10), with RTs for two tokens being considerably shorter than for one token. In other words, strings of repeated letters behaved more plural-like than actual plural nouns. This made the strings problematic as a baseline condition to which singular and plural nouns could be compared and, consequently, they were not included in the analysis. A possible explanation for this plural-like effect may be that a string of letters is perceived as a plurality of symbols (many letters) rather than a single object (one string), which would constitute a possible confounding factor in the counting task. This possibility was tested in Experiment 4.

CHAPTER IV

NUMBER MISMATCH MEETS MARKEDNESS[28]

1 Introduction and chapter overview

In Experiment 1, collective singulars (words with a mismatch between the grammatical number and the lexically specified number) gave rise to a SNARC effect driven by their grammatical singularity, namely a strong left-hand preference. This is consistent with the hypothesis that early numerical representation for those nouns is built based on grammatical number information alone and it is later modified by lexical-semantic or pragmatic factors (see the discussion in Section 3.6 of Chapter II). There are other noun classes, aside from collective nouns, where the conflict between the grammatical number and the lexical number is also present. For instance, the word *glasses* can refer to a single object (a pair of glasses) despite being grammatically plural. Different lexical properties of those noun classes may affect the automatic extraction of number values in different ways.

[28] The experiment presented in this chapter is also described in Gulgowski & Błaszczak (2018).

Using a more diverse sample of stimuli can help verify whether the same mechanism of automatically activating the numerical meaning consistent with the grammatical number extends also to other classes of nouns with a number mismatch. Experiment 4 investigated the early numerical interpretation of three types of words: collectives, *pluralia tantum* and mass nouns. Ordinary countable nouns with no number mismatch were used as control. Additionally, Experiment 4 was intended to examine further the role of morphological marking (the markedness effect found in Experiment 3). For this reason, the type of number morphology was manipulated by using morphologically marked and unmarked singulars. The experimental technique was based on the numerical Stroop interference effect elicited in a word counting task.

The present chapter introduces the three number-mismatching noun types in more detail. This is followed by a description of the method chosen for the experiment and the specific research questions, hypotheses and predictions. Next, the experimental design (with materials and procedure), data analysis and results are presented. The chapter ends with the summary and discussion.

2 Background: Form and meaning conflict

There are at least three kinds of words with a conflict between the value of the word's grammatical number (reflected in its morphological form) and the lexical number (encoded in its lexical semantics). This conflict exists for collectives, *pluralia tantum* and mass nouns.

Collective nouns (e.g., *committee*) were extensively discussed in Chapter II (Section 2). They refer to a collection with multiple salient members. This conceptual plurality can, in some dialects of English, trigger a plural subject-verb agreement for grammatically singular collectives (Bock et al., 2006; Humphreys & Bock, 2005), as illustrated in sentence (17).

(17) *The committee has/have finally made a decision.*

Pluralia tantum (e.g., *glasses*) are nouns whose grammatical number is always plural, but which can nevertheless refer to a single object. For example, in sentence (18), the word *glasses* most likely refers to a single pair of glasses despite being grammatically plural. *Pluralia tantum* require plural agreement.

(18) *Her favorite reading glasses *was/were on the table.*

Mass nouns (e.g., *snow*) are nouns typically denoting some quantity of unindividuated substance or abstract concepts. They take a default singular number value for the purposes of agreement and generally resist pluralization without an accompanying change in meaning or a contextually salient unit of measurement (e.g., *two milks* meaning *two bottles of milk*). Mass nouns require singular agreement.

(19) *The milk was/*were cold.*

As was already discussed for collective nouns in Chapter II, research on agreement attraction indicates that the specification of a noun as grammatically plural or singular can be stronger than its lexically or pragmatically determined number in the computation of subject-verb agreement (Bock et al., 2001a; Bock & Eberhard, 1993). The other categories of words with a number mismatch have been used as stimuli less commonly than collectives, but some empirical evidence exists suggesting that they may behave similarly in terms of agreement attraction. In Bock et al. (2001), *pluralia tantum* and bipartite attractors (e.g., *groceries*, *scissors*) led to more instances of plural agreement than singular nouns in this function, despite being conceptually ambiguous in terms of number.

Experiment 1 provided evidence supporting the possibility that singular collective nouns are initially understood as denoting a single entity, with the conceptual plurality of the constituent parts receiving more activation at a later processing stage. Similarly, it can be expected that the grammatical plurality of *pluralia tantum* words should automatically trigger conceptual plurality (e.g., automatically associating the word *scissors* with something plural) which would then have to be suppressed (e.g., assigning a singular interpretation to *one pair of scissors*). Likewise, grammatically singular mass nouns should activate the concept of singularity, which is later replaced by the idea of unspecified amount.

3 Experiment 4

3.1 Method

The technique used in Experiment 4 was once again based on the numerical Stroop interference (see Section 6.1 of Chapter I for more details).

3.2 Research question and predictions

If the automatic extraction of numerical information in the early stages of word processing is driven exclusively by the grammatical number for all words, then activating the notion of singularity for grammatically singular nouns and the notion of plurality for grammatically plural nouns should take place before the lexical semantics is fully accessed. Grammatically singular collective (e.g., *team*) and mass (e.g., *sand*) nouns should pattern with ordinary countable singulars (e.g., *tree*) in terms of the Stroop congruity effect in the counting task. Responses for those nouns should be longer in the visually double than in the visually single condition, provided that they are morphologically marked for number. On the other hand, *pluralia tantum* nouns should resemble ordinary countable plurals. Responses for those nouns should be longer in the visually single than in the visually double condition.

Another prediction for Experiment 4 was that, if the initial numerical interpretation is driven by morphosyntactic cues, it should be possible to replicate the markedness effect of number morphology from Experiment 3 for all marked singulars, regardless of their type.[29] Marked singular nouns should differ from both marked plural and unmarked singular nouns, producing significantly shorter reaction times in the visually single than in the visually double condition. Unmarked singular nouns should not present any congruity effect, or the effect should be considerably smaller than for marked singulars.

[29] Plural nouns are generally marked with an overt suffix in Polish, so this possibility could only be tested for singulars.

3.3 Design

3.3.1 Materials

In the present experiment, the following 244 items were used:

- 80 prototypically countable nouns
  - 40 singular nouns (e.g., *rower* ‘bike’)
  - 40 plural nouns (e.g., *młotki* ‘hammers’)
- 40 mass nouns (e.g., *piasek* ‘sand’)
- 40 collective singular nouns (e.g., *stado* ‘herd’)
- 44 *pluralia tantum* nouns (e.g., *nożyce* ‘scissors’)[30]
- 20 number-neutral words, including adverbs (e.g., *żółto* ‘in a yellow color’), particles (e.g., *czyż* ‘alas’), prepositions (e.g., *przez* ‘through’) and conjunctions (e.g., *gdyż* ‘because’)
- 20 white rectangles corresponding roughly in size to the average area of the words used in the experiment

To check the possible influence of morphological markedness on the interpretation of grammatically singular nouns, forms with and without a suffix were selected. Twenty countable nouns (e.g., *krow-a* ‘cow-NOM.SG’), 12 collective nouns (e.g., *grup-a* ‘group-NOM.SG’) and 17 mass nouns (e.g., *złot-o* ‘gold-NOM.SG’) were morphologically marked with a suffix, the remaining countable (*stół-Ø* ‘table-NOM.SG’), collective (e.g., *tłum-Ø* ‘crowd-NOM.SG’) and mass (e.g., *olej-Ø* ‘oil-NOM.SG’) nouns were unmarked. All plural nouns had an overt number suffix.

Experiment 4 included two new neutral control conditions. Number-neutral words were chosen instead of strings of repeated letters to increase the likelihood of them being treated as a coherent whole (a word) and in that way to improve their suitability as the baseline condition.

[30] There were 20 unique singular collective and 22 unique *pluralia tantum* nouns. Each singular collective and *pluralia tantum* item was used twice to make the number of items in these group comparable to the number of items in the singular count, plural and mass group.

The inclusion of non-linguistic stimuli in the form of white rectangles was motivated by the unexpected results for number-neutral strings of repeated letters in Experiment 3, which gave rise to a Stroop effect with faster responses in the visually double condition. Comparing words with rectangles should allow to test the possibility that the visual plurality of letters in letter strings generates its own plurality-related Stroop effect in the counting task.

Each item appeared on the screen both as a single token or as two copies. The total number of trials in the experiment was 488. The presentation order was fully randomized for each participant.

3.3.2 Procedure

The procedure was similar as in Experiment 3. The experiment started with a greeting message and instructions displayed on the screen. The message explained that the task of the participant was to count the number of words (e.g., *zeszyt* 'notebook') or white rectangles appearing on the screen by pressing the left arrow key when the item was visible as a single token (e.g., *zeszyt*) or the right arrow key when the item appeared on the screen twice (e.g., *zeszyt zeszyt*).

Each trial started with a fixation cross in the middle of the screen. The cross remained visible for 300 ms and was followed by 300 ms of blank screen and then either a single token of an experimental item or an item repeated twice appeared. The item(s) remained on the screen until the participant reacted by pressing the left or the right arrow. If the response was incorrect, there was a 400 ms feedback informing the participant about the mistake. If the reaction was correct, there was no feedback. In every case the trial ended with 300 ms of a blank screen before the next trial began. See Figure 12 for the visual representation of the structure of a trial.

The experiment proper was preceded by a training session that followed the same procedure with the exception that a feedback was given for both incorrect and correct responses. There were 16 training trials (10 words and 6 rectangles). The training ended with a message informing about the number of correct and incorrect responses, encouraging the participant to ask questions and informing about the possibility of repeating the session. No training item appeared later in the experiment proper.

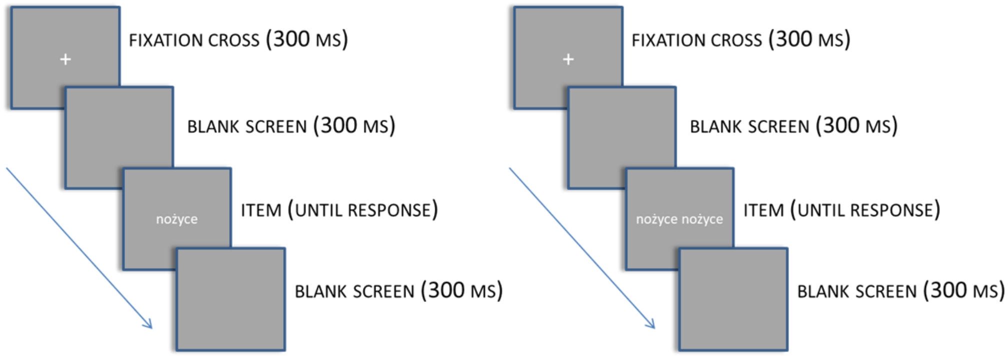


Figure 12: The structure of a trial in Experiment 4 in the visually single and visually double condition.

There were three breaks, after each 122 trials. Each experiment session lasted approximately 15-20 minutes. The participants could proceed when ready by pressing the space bar. The experiment was designed and presented using the PsychoPy software (version 1.84.2) (Peirce 2007; 2009).

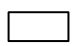
3.3.3 Participants

Thirty-two students of the Institute for English Studies of the University of Wrocław (24 women) took part in the experiment. Participants were all native speakers of Polish. The average age was 22 (*SD*=3.47).

3.4 Results: Reaction Times

The data were cleaned first by removing incorrect responses and then by eliminating the trials with reaction times (RT) 2 standard deviations above or below the mean in each condition for every participant. This resulted in removing 4.7% of accurate responses. The remaining trials were subjected to tests performed with the SPSS software (Version 22). Average RT and percentage of correct responses for the main experimental conditions are presented in Table 13.

Table 13: Mean reaction times and accuracy (percent correct) in Experiment 4 for different types of items displayed as visually single or double (standard errors in parentheses).

Item Type		Visual Number					
		Visual 1		*Visual 2*		*Congruity (Visual 1-Visual 2)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Unmarked Count Sg.	*rower* 'bike'	440 (14)	97.50%	448 (15)	97.03%	-8	0.47%
Marked Count Sg.	*krowa* 'cow'	444 (15)	98.44%	440 (15)	97.03%	4	1.41%
Unmarked Mass	*beton* 'concrete'	442 (13)	97.55%	438 (14)	96.46%	4	1.09%
Marked Mass	*złoto* 'gold'	441 (13)	97.97%	437 (15)	97.24%	4	0.73%
Unmarked Coll.	*klan* 'clan'	436 (13)	98.43%	440 (13)	94.79%	-4	3.64%
Marked Coll.	*załoga* 'crew'	445 (14)	96.54%	435 (13)	97.32%	10	-0.78%
Marked Plural	*klucze* 'keys'	447 (16)	97.11%	446 (14)	97.27%	1	-0.16%
Pluralia tantum	*nożyce* 'scissors'	447 (14)	98.01%	441 (13)	96.38%	6	1.63%
Number-Neutral Word	*przez* 'through'	448 (4)	98.4%	442 (5)	95.6%	6	2.8%
Number-Neutral Rectangle		516 (4)	95%	474 (5)	95.9%	42	-0.9%

3.4.1 Grammatically singular nouns (countable, mass, collective)

To test the possibility that all morphologically marked singular nouns, regardless of their lexical number, are initially processed in the same way, a **3×2×2 ANOVA** was conducted exclusively on grammatically singular items using RT as the dependent variable with the following independent factors:

- Item Type (countable, mass, collective)
- Morphology (marked, unmarked)
- Visual Number (visual 1, visual 2)

The complete results of the ANOVA test are given in Table 14.

Table 14: Results of an Item Type×Morphology×Visual Number ANOVA comparing the mean reaction times for all grammatically singular nouns (countable, mass, collective) in Experiment 4.

Source	*df*		*F*		*p*		Partial Eta Sq.	
	Subjects	Items	Subjects	Items	Subjects	Items	Subjects	Items
Item Type	2,62	2,114	0.75	0.94	.476	.394	.02	.02
Morph.	1,31	1,114	0.05	0.24	.817	.629	.00	.02
Vis. Number	1,31	1,114	0.18	0.12	.672	.725	.01	.00
Item Type× Morph.	2,62	2,114	0.20	0.02	.818	.983	.01	.00
Item Type× Vis. Number	2,62	2,114	0.68	0.32	.509	.724	.02	.01
Morph.× Vis. Number	1,31	1,114	4.49	2.36	.042*	.127	.13	.02
Item Type× Morph.× Vis. Number	2,62	2,114	0.91	0.57	.407	.567	.03	.01

There was no main effect of any factor. The Morphology×Visual Number interaction was statistically significant by subjects (although not by items) indicating that the type of morphology affected the ability to count grammatically singular nouns (countable, mass and collective nouns combined). Unmarked singular nouns were on average slightly faster in the visually single (M=439 ms SE=13) than in the visually double condition (M=442 ms SE=14). In contrast, marked singulars generated faster reaction times in the visually double (M=437 ms SE=14) than in the visually single (M=443 ms SE=14) condition.

This outcome contradicts the part of the hypothesis concerning the influence of number morphology on the performance in a counting task, which predicted the opposite results for marked and unmarked items. The triple Item Type×Morphology×Visual Number interaction was not significant, suggesting that all three item types were similarly affected by the visual number manipulation. Figure 13 presents a visualization of the data.

Finally, the Item Type×Visual Number interaction was not significant. This may suggest that grammatically singular words with a form-meaning conflict (mass and collective nouns) do not differ from ordinary countable nouns in terms of early numerical interpretation.

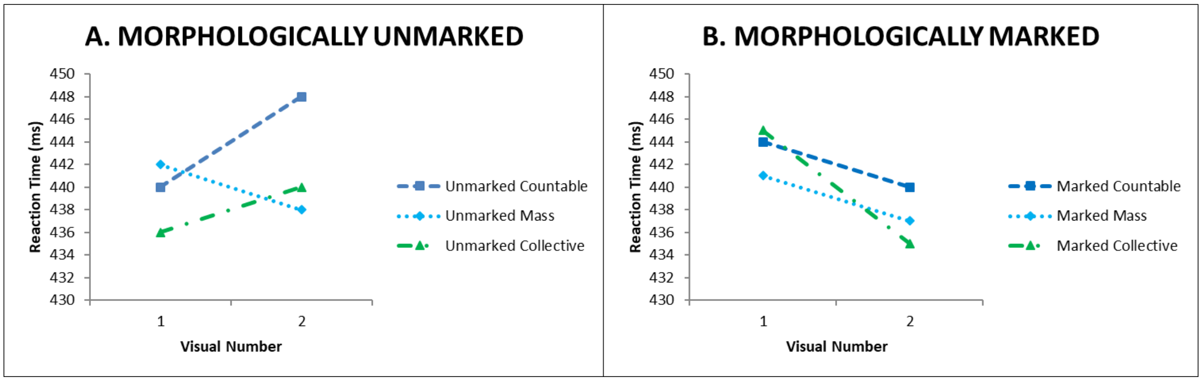


Figure 13: The interaction of Morphology, Item Type and Visual Number for grammatically singular nouns (countable, mass, collective) in Experiment 4.

3.4.2 Grammatically plural nouns (marked plural, pluralia tantum)

To find out whether *pluralia tantum* nouns behaved in the counting task like countable plural nouns, a **2×2 ANOVA** was conducted exclusively on grammatically plural items using RT as the dependent variable with the following independent factors:

- Item Type (marked plural, *pluralia tantum*)
- Visual Number (visual 1, visual 2)

There was no significant main effect of Item Type ($F_1(1,31)=0.57$ $p=.458$; $F_2(1,82)=0.73$ $p=.395$) or Visual Number ($F_1(1,31)=0.25$ $p=.623$; $F_2(1,82)=0.49$ $p=.485$). The Item Type×Visual Number interaction was also not statistically significant ($F_1(1,31)=0.43$ $p=.516$; $F_2(1,82)=0.31$ $p=.581$), so *pluralia tantum* and countable plurals did not differ in their interaction with visual number (as predicted). However, a very small congruity effect (the difference between the visual 1 and visual 2 conditions), especially for plurals, makes interpreting this result problematic. Figure 14 presents a visualization of the data.

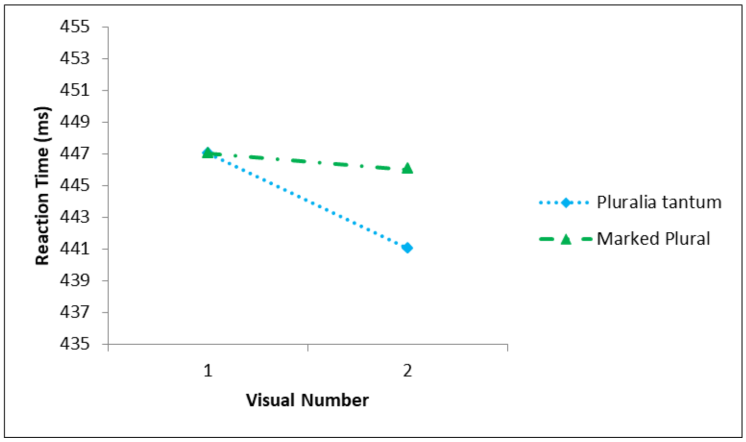


Figure 14: The interaction of Item Type and Visual Number for grammatically plural nouns (marked plural, *pluralia tantum*) in Experiment 4.

3.4.3 Rectangles vs. words

In order to test the possibility that the plurality of characters in a string of letters can interfere with the task of counting such strings, a **2×2 ANOVA** was conducted exclusively on number-neutral items using RT as the dependent variable with the following independent factors:

- Item Type (neutral words, rectangles)
- Visual Number (visual 1, visual 2)

There was a significant main effect of Item Type ($F_1(1,31)=60.09$ $p<.001$ $\eta_p^2=.66$; $F_2(1,38)=128.77$ $p<.001$ $\eta_p^2=.77$). There was also a significant main effect of Visual Number ($F_1(1,31)=11.21$ $p=.002$ $\eta_p^2=.27$; $F_2(1,38)=21.79$ $p<.001$ $\eta_p^2=.36$). The interaction between the two factors was significant as well ($F_1(1,31)=11.00$ $p=.002$ $\eta_p^2=.26$; $F_2(1,38)=13.51$ $p=.001$ $\eta_p^2=.26$). Manipulating Visual Number produced a bigger effect for rectangles than for words. Figure 15 provides a visualization of the data. A visual inspection of the data reveals that white rectangles gave rise to a kind of Stroop interference, with faster responses in the visually double condition. The source of the interference-like effect for number-neutral items, therefore, is unlikely to be the plurality of letters in letter strings.

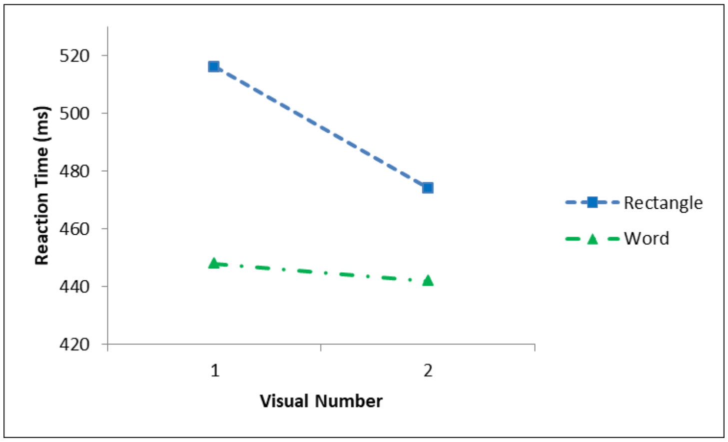


Figure 15: The interaction of Item Type and Visual Number for number-neutral items (rectangles, words) in Experiment 4.

3.4.4 Global ANOVA with number-neutral words as baseline

In order to determine whether any of the major conditions behaved markedly different from the number-neutral baseline condition, a **9×2 ANOVA** was conducted on all items (minus white rectangles) using RT as the dependent variable with the following independent factors:

- Item Type (marked singular, unmarked singular, marked mass, unmarked mass, marked collective, unmarked collective, marked plural, *pluralia tantum*, neutral words)
- Visual Number (visual 1, visual 2)

Number-neutral words were chosen for this test over white rectangles because they showed significantly less difference between the visual 1 and visual 2 conditions, which makes them a better baseline. There was no significant main effect of Item Type ($F_1(8,248)=1.00$ $p=.439$; $F_2(8,215)=1.03$ $p=.413$) or Visual Number ($F_1(1,31)=0.46$ p=.504; $F_2(1,215)=0.60$ p=.441). The interaction between the two factors was also not significant ($F_1(8,248)=0.79$ $p=.613$; $F_2(8,215)=0.59$ $p=.789$).

4 Discussion

In a test limited to marked and unmarked grammatically singular nouns (countable, mass, collective), the two-way interaction of morphological markedness with visual number was significant. This indicates that the presence or absence of an overt number suffix made a difference in terms of the numerical Stroop interference, which was partly consistent with the predictions. However, the nature of this interference was inconsistent with the results of Experiment 3. A singular-congruity effect (shorter RT in the visually single condition, longer RT in the visually double condition) was present only in unmarked nouns, whereas in Experiment 3 unmarked singulars gave rise to a weaker singular-congruity effect. In the same test, the Item Type×Visual Number interaction and the triple interaction of Item Type×Morphology×Visual Number were not significant, suggesting that grammatically singular words with a form-meaning conflict (collectives, mass nouns) may behave like ordinary countable singular nouns in terms of early numerical interpretation. This, in turn, is in line with the possibility that the early automatic extraction of numerical concepts is driven primarily by the grammatical number value of the word, with no regard for the lexical specification. However, because of the unexpected effect of morphological markedness, the interpretation of the results presented above is problematic.

Another test involved only grammatically plural words. *Pluralia tantum* nouns did not differ significantly from countable plurals, matching the prediction that nouns with the same grammatical number value should behave in the same way in terms of the numerical Stroop effect, regardless of their lexical number. However the reliability of this result is, once again, questionable because nouns in these conditions showed overall very little congruity effect (difference between the visually single and visually double display).

Finally, no major condition differed statistically from number-neutral words used as a baseline.

The two experiments provided mixed results. Experiment 4 failed to replicate the effect of morphological markedness from Experiment 3. When all grammatically singular nouns (countable, mass, collective) were compared in one test, the result showed a singular-congruity effect only for morphologically unmarked nouns, contradicting the findings of Experiment 3. The reason for the difference between the two experiments is unclear. It is possible that different experimental designs put different emphasis on number morphology. Specifically, the greater number of noun types in Experiment 4, including noun classes with a conflict between their grammatical and semantic number, may have made the overt number markers less reliable as cues for numerical interpretation.

Experiment 4 did manage to answer the question about the multiplicity of characters in letter strings possibly being a source of number interference in a counting task in Experiment 3. White rectangles produced a larger Stroop-like effect (faster responses in the visually double condition) than number-neutral words, meaning that the general two-item preference observed for number-neutral items in both experiments is not a result of the visual plurality of components (individual letters).

CHAPTER V

COMPOSITIONAL SEMANTICS (NEGATION)

1 Introduction and chapter overview

The number reading of a noun is sometimes a function of the context in which it occurs. For example, a singular noun in a generic expression refers to an unspecified number of things or members of a class. Another example is the influence of sentential negation, questions and conditional constructions on the meaning of plural nouns. The numerical interpretation of a plural in such environments changes from the usual “more than one” (exclusive) to “one or more” (inclusive). A question relevant to number processing is at which stage context starts to interact with the numerical interpretation of a noun.

Studying the way in which sentential operators affect the numerical representation of a word’s meaning should provide more information about how the information conveyed by grammatical number is compositionally integrated with the wider logical structure of a sentence. It is also relevant for the debate about the amount of incrementality in language processing. In Experiment 5, plural nouns were placed in the scope of sentential negation to assess whether this environment affects the process of early automatic extraction of number concepts. The technique was based on the numerical Stroop interference elicited with a word counting task.

The present chapter introduces the concepts of exclusive and inclusive plurality and the question of incrementality in language processing. Next, the results of past research on the effects of negation in sentence comprehension are discussed. This is followed by a presentation of the chosen methodology, research question and predictions addressed in the current experiment. After that, a description of the experimental design (with materials and procedure), data analysis and results are presented. The chapter ends with summary and discussion.

2 Background: Inclusive plurality and negation

2.1 Inclusive and exclusive plurals

The typical numerical reading of a plural noun in English, Polish and many other languages is "more than one". It means that a plural noun refers to a group of at least two members (the ***exclusive "two or more" interpretation***). Sentence (20) would be incorrect, or at least inappropriate, if the speaker saw just one squirrel.

(20) *I have seen squirrels in the park.*

However, plural nouns occurring in questions, conditional constructions and, most notably, negative sentences are typically understood as referring not to a group of individuals, but to any number of individuals (the ***inclusive "one or more" interpretation***).

(21) a. *Have you seen any squirrels?*
[I can answer "yes" truthfully even if I saw just one squirrel.]

b. *If you see any squirrels, let me know.*
[The speaker wants to be notified even if only one squirrel was seen.]

c. *I haven't seen any squirrels.*
[The sentence is false even if I saw only one squirrel.]

According to a generalization proposed in the literature, the crucial factor at play responsible for the exclusive or inclusive reading of a plural is the logical property of monotonicity: plural nouns have an exclusive reading in upward monotone contexts and an inclusive reading in downward monotone ones (Anand et al., 2011; Farkas & de Swart, 2010; Sauerland et al., 2005; Zweig, 2009).[31] Experimental evidence providing support for this generalization can be found in Anand et al. (2011). Using the image verification technique, the authors examined the interpretation of plural nouns in the restrictor (a downward monotone position) and the nuclear scope (an upward monotone position) of the quantifier *each*. As predicted by the generalization, nuclear scope plurals were interpreted exclusively more often than restrictor plurals.[32]

A possible explanation for the influence of monotonicity is offered by the scalar-implicature theory of plural meaning (Spector, 2007). According to this account, the "basic" interpretation of plural nouns is inclusive ("one or more"). However, if a reference to a single entity was intended, the speaker would use a singular form with a more specific meaning of "exactly one". From this, comprehenders can infer that the most likely reading of a plural noun is exclusive ("two or more"). Because inferences of this type are less likely to arise in downward entailing environments (Frazier, 2008), the exclusive interpretation of plurals embedded in such contexts is weakened or cancelled.

The scalar-implicature hypothesis was tested by Tieu et al. (2014) using a truth-value judgment task. They asked children and adult participants to evaluate the truth of statements referring to

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[31] Monotonicity is an inference-related property of predicates. Upward monotone predicates allow inferences from a subset to a superset (example (i)) and downward monotone predicates allow inferences in the opposite direction (example (ii)).

(i) I have an apple => I have a fruit

(ii) I don't have an apple <= I don't have a fruit

For more information see, among others, Nouwen (2010), Penka & Zeijlstra (2010), Spector (2007) or Tunstall (1998). It should be noticed that the monotonicity of interrogative sentences is problematic (for a discussion, see Giannakidou, 1998; Gutiérrez-Rexach, 1997; Progovac, 1993 or van der Wouden, 1997). Similarly, the downward monotonic properties of conditionals have been questioned in the literature (Gajewski, 2011; Heim, 1984; von Fintel, 1999).

[32] The difference between the two positions was, in fact, quite small and the overall acceptance for plural nouns referring to single objects (inclusive reading) was relatively high, even in the (upward monotone) nuclear scope of the quantifier, where the exclusive reading was predicted to be dominant. In another experiment described in the same paper, Anand and colleagues found a much higher degree of exclusivization of plural meaning in (upward monotone) affirmative sentences with no quantifier. This suggests that monotonicity, although important, may not be the only factor affecting the inclusive/exclusive interpretation of plurals.

short stories told by the experimenter. Critical words in the statements were singular and plural nouns and the statements were either affirmative (upward monotone) or negative (downward monotone). The results indicated that both age groups computed more exclusive plural interpretations in affirmative than in negative conditions, which replicated the result of Anand et al. (2011). Crucially, children were significantly less likely to assign exclusive readings to plurals in upward monotone affirmative sentences than adults. Because children have been independently demonstrated to be less capable of properly using scalar implicatures (Papafragou & Musolino, 2003), this outcome was taken to support the implicature model of plural interpretation.

2.2 Negation and parser incrementality

One of the major topics in the early days of modern psycholinguistics concerned the degree of ***incrementality*** in language, that is, whether language processing mechanisms make use of all available sources of information (from syntax, lexical semantics, discourse) as soon as possible or is there a strict sequence determining when each information source is available. Incrementality is thus a question of the role of broadly understood context in the processing of the unfolding linguistic input. A non-incremental approach (e.g., Frazier, 1987) assumes the existence of processing stages, with different types of information being available at different stages. In contrast, an incremental approach (e.g., Boland, Tanenhaus, & Garnsey, 1990) assumes a more or less immediate application of all contextual information to each encountered word. Evidence obtained over several decades indicates that human language-parsing mechanisms are highly incremental. For example, in the eye-tracking study by Tanenhaus et al. (1995), comprehenders directed their gaze at visually displayed objects immediately after hearing the words used to describe those objects, instead of waiting for the clause to unfold completely. This automatic interpretation of linguistic expressions was affected very early by context, including extra-linguistic information. Moreover, the incrementally built interpretation of a sentence fragment can be used to predict what might come next, like anticipating the properties of the object from the semantics of the verb plus the subject (Kamide et al., 2003).[33]

However, apparently not every kind of information is equally rapidly integrated with the incrementally built interpretation. In an ERP study, Fischler et al. (1983) found an increased N400 (an ERP component associated, among other things, with semantic anomalies and plausibility in context) for the last word of false affirmative sentences, like (23), with respect to the true sentences, like (22).

(22) *A robin is a bird.* [true]

(23) *A robin is a tree.* [false][increased N400]

In contrast, false negative sentences, like (24), did not elicit an increased N400 in comparison to true negative sentences, like (25). In fact, the N400 effect was reversed for negative sentences, with the logically true sentences showing a bigger N400 amplitude than false sentences.

(24) *A robin is <u>not</u> a bird* [false]

(25) *A robin is <u>not</u> a tree* [true][increased N400]

According to the authors, this result suggests that the interpretation of a negative expression proceeds in two steps: the affirmative version of a negated sentence is evaluated first, before the truth-value of the whole proposition is reversed by negation. At the first stage of comprehension *A robin is a bird* and *A robin is not a bird* are equivalent. This idea is known as the ***two-step simulation hypothesis*** (Kaup et al., 2006; Spychalska, 2011).

The results of a more recent ERP study by Lüdtke et al. (2008) paint a similar picture. The participants read affirmative and negative sentences (e.g., *In the front of the tower there is a/no ghost*) followed after a delay by an image depicting either the object named in the sentence or an unrelated object. The sentence-image delay was either short (250 ms) or long (1500 ms). There was a priming effect (reduced N400) for pictures with related objects after both

[33] Incrementality is usually studied in language comprehension. Evidence for some degree of (task-dependent) incrementality in language production can be found in Ferreira & Sweets (2002).

affirmative and negative sentences. That was consistent with the possibility that comprehenders build an early representation of the meaning of a negative sentence ignoring the impact of negation. The phrase *a ghost* and the phrase *no ghost* similarly primed the picture of a ghost. The priming effect was observed regardless of the delay. However, manipulating the sentence-picture delay did influence the effect of negation in a different way. With a shorter delay, a difference in the EEG recording between affirmative and negative sentences was detected in a relatively late time window (starting around 550 ms after picture onset). With a longer delay, an affirmative/negative difference appeared during a considerably earlier time window (starting around 250 ms after picture onset). This was taken as evidence that negation needed some time to be fully integrated into the sentence interpretation. Only after a sufficiently long sentence-picture delay was negation information available early on for the verification task decision (although still unable to cancel the priming effect). A similar observation concerning the impact of negation on ERP components can be found in Kutas and Federmeier (2011): “[In] some cases (e.g., negation in the absence of pragmatic licensing), information that ultimately impacts plausibility judgments is not active in time to modulate N400 activity” (p. 633).

If the two-step simulation hypothesis of negation processing is correct and delaying the semantic contribution of negation is a common parsing mechanism, then the conversion of the interpretation of a plural noun from exclusive to inclusive should also take place at a later stage, perhaps during sentence-level information integration.

3 Experiment 5

3.1 Method

The technique used in Experiment 5 was once again based on the numerical Stroop interference (see Section 6.1 of Chapter I for more details).

3.2 Research question and predictions

Is the early automatic interpretation of a plural noun in the scope of sentential negation inclusive or exclusive? The present experiment explored that issue using a design based on the numerical Stroop interference in a word counting task by placing plural nouns in affirmative sentences (upward monotone environment) and their negated versions (downward monotone environment).

The predictions for affirmative sentences were relatively straightforward. Because the default interpretation of plurals in such sentences is exclusive ("two or more"), faster reactions were expected in the visually double condition than in the visually single condition. The predicted Stroop interference for plural nouns embedded in affirmative sentences should, therefore, resemble the effect found for plural nouns presented in isolation in Berent et al. (2005) and in Experiment 3 of the present work.

The crucial question concerned the behavior of plural nouns in the scope of sentential negation. If a proper integration of negation with the sentence meaning requires a delay, the early interpretation of plurals in the scope of negation should be exclusive, that is, they should give rise to a conceptual plurality ("two or more"). In this case, plural nouns in negative sentences should produce a Stroop interference similar to plural nouns in affirmative sentences. If, on the other hand, negation has an immediate effect in the form of imposing an inclusive ("one or more") reading on a plural noun very soon after it is encountered, plural nouns in the scope of sentential negation should not give rise to a clear numerical Stroop interference, because inclusive reading is akin to being number-neutral.

3.3 Design

3.3.1 Materials

The experimental items consisted of 60 words:

- 30 singular nouns (e.g., *królik* 'rabbit')

- 30 plural forms created from the singulars (e.g., *króliki* ‘rabbits’)

The words were embedded in 60 affirmative sentences and in 60 negative sentences, represented in examples (26) and (27), respectively.

(26)	a	*Adam*	*widział*	*małego*	***królika.***
		Adam	see.3SG.PST.IPFV	small.ACC.SG	rabbit.ACC.SG
	b	*Adam*	*widział*	*małe*	***króliki.***
		Adam	see.3SG.PST.IPFV	small.ACC.PL	rabbit.ACC.PL

(27)	a	*Adam*	*nie*	*widział*	*żadnego*	***królika.***
		Adam	NEG	see.3SG.PST.IPFV	any.GEN.SG	rabbit.GEN.SG [34]
	b	*Adam*	*nie*	*widział*	*żadnych*	***królików.***
		Adam	NEG	see.3SG.PST.IPFV	any.GEN.PL	rabbit.GEN.PL

The critical nouns were always sentence-final and they were preceded by an adjective (in affirmative sentences) or by the word *żaden* ‘any/no’[35] (in negative sentences).

Additionally, 40 filler sentences were created (20 affirmative and 20 negative), all ending with an adverb (e.g., *szybko* ‘fast’).

(28)	*Lidka*	*jechała*	*bardzo*	***szybko.***
	Lidka	drive.3SG.PST.IPFV	very	fast

(29)	*Lidka*	*nie*	*jechała*	*wcale*	***szybko.***
	Lidka	NEG	drive.3SG.PST.IPFV	at.all	fast

There were 160 stimuli in total (120 critical sentences and 40 filler sentences). Each sentence appeared with the final word as a single token (e.g., *królika*) or repeated twice (e.g., *królika królika*). Therefore the total number of trials in the experiment was 320. The presentation order was fully randomized for each participant.

[34] The direct object of a negated transitive verb in Polish is obligatorily marked for genitive, a phenomenon known as *Genitive of Negation* (Błaszczak, 2001a, 2001b, 2007; Przepiórkowski, 1997; Witkoś, 1998).

[35] The word *żaden* is similar to English *any* in that it is licensed by sentential negation. It is inflected like an adjective and it was chosen as an additional marker of negation to strengthen the possible effect.

3.3.2 Procedure

The procedure was based on the experiment presented in Patson & Warren (2010), who extended the numerical Stroop interference technique to words in context (see Section 6.1 of Chapter I and Section 2 of Chapter VI). Each sentence was introduced by a fixation cross which remained on the screen for 300 ms. Sentences were presented in one- or two-word chunks displayed at the center of the screen. The participants moved to the next chunk by pressing the space bar. The last chunk was always displayed in blue font and it was either a single word (e.g., *królika* 'rabbit') or the same word repeated twice (e.g., *królika królika* 'rabbit rabbit'). The participants were instructed to decide how many blue font words they see on the screen at the end of each sentence by pressing the left arrow key (one word) or the right arrow key (two words).[36] On 56 out of 320 trials (balanced across conditions) the sentence was followed by a comprehension question displayed in green font with two possible answers displayed below the question on the left and right side of the screen. The questions concerned the verb, object, adjective or the meaning of the whole sentence (see Table 15). The participants indicated their choice by pressing the left or right arrow key.

The experiment proper was preceded by instructions and a training session consisting of 14 sentences with four comprehension questions. After every counting and comprehension decision, there was a 1000 ms feedback display informing the participant whether the answer was correct or incorrect. In the experiment proper, a feedback message appeared only after an incorrect response. The training session ended with a message informing about the number of correct and incorrect responses. No training item appeared later in the experiment.

[36] In Patson & Warren (2010) the last word was never doubled, instead the final chunk contained either the last word presented as a single token (visually single) or the last two words of the sentence (visually double). The doubling in the present experiment was introduced to increase the salience of grammatical number in the visually double trials by having two plural nouns visible on the screen.

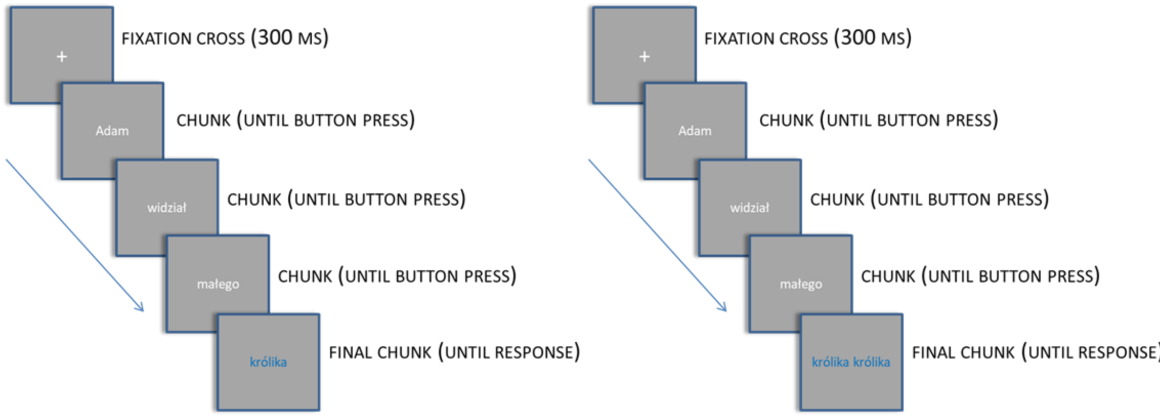

Figure 16: The structure of a trial in Experiment 5 in the visually single and visually double condition.

Halfway through the experiment there was a message informing about a break. The participant could proceed when ready by pressing the space bar. A single experimental session lasted around 20 minutes.

The experiment was designed and presented using the PsychoPy software (version 1.83.03) (Peirce, 2007, 2009).

3.3.3 Participants

Thirty-one students of the Institute for English Studies of the University of Wrocław (8 men) took part in the experiment. Participants were all native speakers of Polish. The average age was 19.9 (*SD*=1.27).

3.4 Results: Comprehension questions

The task in the present experiment required participants to count the words included in the final chunk of each sentence. This task could result in a strategy whereby participants would simply not pay attention to the sentence fragments preceding the critical final chunk. In this case, the results would reflect the shallow (non-compositional) processing of most sentences, and any possible impact of sentential negation would be lost. To rule out this possibility, questions about sentences were included in roughly 20% of all trials. The questions targeted specific sentence parts (the adjective, the adverb, the object or the verb) or required a global comprehension of the entire sentence. Table 15 presents examples of each question type and the accuracy of participants' responses.

Table 15: Average accuracy (percent correct) for different types of comprehension questions in Experiment 5 (standard deviations in parentheses).

Question Type		*Accuracy*
Adjective Question	*Jakich bandytów ścigał policjant?* 'What kind of bandits did the policeman chase?'	99.2% (4.5)
Adverb Question	*Jak pracował górnik?* 'How did the miner work?'	99.5% (2.6)
Object Question	*Co widział Adam?* 'What did Adam see?'	99.1% (3.1)
Sentence Question	*Czy malarz czyścił pędzel?* 'Did the painter clean the brush?'	90.1% (9.4)
Verb Question	*Co robiła Magda?* 'What did Magda do?'	97.7% (4.9)

While answers to the questions concerning the truth or falsity of the whole sentence were somewhat less accurate than to other types of question, the overall accuracy for all questions was relatively high (over 90%). This suggests that participants did pay attention to the sentence meaning, including its polarity (affirmative vs. negative).

3.5 Results: Reaction times

The data were cleaned first by removing all incorrect responses and then by eliminating all trials with response times (RT) 2 standard deviations above or below the mean for each participant in each condition. This resulted in removing 5.1% of correct trials. The remaining trials were subjected to tests performed with the SPSS software, version 22.

A **2×2×2 ANOVA** was conducted with RT as the dependent variable and the following independent factors:

- Polarity (affirmative, negative)
- Grammatical Number (singular, plural)
- Visual Number (visual 1, visual 2)

There was no main effect of Polarity ($F_1(1,30)=0.62$ $p=.436$; $F_2(1,116)=0.65$ $p=.421$) or Grammatical Number ($F_1(1,30)=0.72$ $p=.404$; $F_2(1,116)=1.25$ $p=.265$). The main effect of Visual Number was not significant by subjects ($F_1(1,30)=1.70$ $p=.203$) but it was significant by items ($F_2(1,116)=8.50$ $p<.01$ $\eta_p^2=.07$). Items presented on the screen as visually single were on average responded to more slowly than items presented as visually double (see Table 16 and the visualization in Figure 17).

Table 16: Mean reaction times and accuracy (percent correct) in the counting task for nouns presented as a single token or repeated twice on the screen in Experiment 5 (standard errors in parentheses).

VISUAL NUMBER		*RT (ms)*	*Accuracy*
Visual 1	*pojazd* 'vehicle'	647 (24)	98.5%
Visual 2	*pojazd pojazd*	637 (25)	98.6%

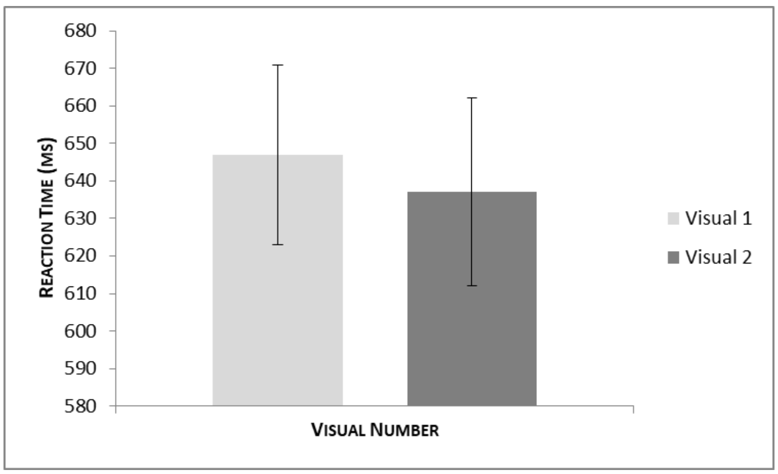

Figure 17: Main effect of Visual Number in Experiment 5 (bars indicate standard errors).

The Polarity×Grammatical Number interaction was not significant ($F_1(1,30)=0.58$ $p=.452$; $F_2(1,116)=0.70$ $p=.405$) and neither was the interaction of Polarity×Visual Number ($F_1(1,30)=0.12$ $p=.728$; $F_2(1,116)=0.03$ $p=.868$).

The interaction of Grammatical Number×Visual Number was significant both by subjects ($F_1(1,30)=8.34$ $p<.01$ $\eta_p^2=.22$) and by items ($F_2(1,116)=14.69$ $p<.001$ $\eta_p^2=.11$). Responses to singular nouns were on average faster in the visually single condition than in the visually double condition. The pattern was reversed for plural nouns. This congruity effect was larger for plural nouns (see Table 17).

Table 17: Mean reaction times and accuracy (percent correct) in the counting task for singular and plural nouns presented as a single token or repeated twice on the screen in Experiment 5 (standard errors in parentheses).

GRAMMATICAL NUMBER		VISUAL NUMBER					
		Visual 1		*Visual 2*		*Congruity (Visual 1-Visual 2)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Singular	*pojazd* 'vehicle.SG.ACC'	637 (23)	98.9%	641 (25)	98.6%	-4	0.3%
Plural	*pojazdy* 'vehicle.PL.ACC'	656 (26)	98.1%	632 (24)	98.7%	24	-0.6%

Crucially, the three-way interaction of Polarity×Grammatical Number×Visual Number was not significant ($F_1(1,30)=0.227$ $p=.637$; $F_2(1,116)=1.337$ $p=.250$), indicating that the manipulation of the visual numerosity had roughly the same effect on nouns in affirmative and negative sentences. This was confirmed by the inspection of the data (see Table 18 and the graphs in Figure 18). If anything, counting singular nouns was more sensitive to polarity than counting plurals as the congruity effect was noticeably bigger in affirmative than in negative sentences for singulars. However, given that the overall interaction was not significant and that the initial predictions concerned only plural nouns, no explanation for this trend is offered here.

Table 18: Mean reaction times and accuracy (percent correct) in the counting task for singular and plural nouns embedded in affirmative or negative sentences and presented as a single token or repeated twice on the screen in Experiment 5 (standard errors in parentheses).

POLARITY	GRAMM. NUMBER	VISUAL NUMBER					
		Visual 1		*Visual 2*		*Congruity (Visual 1-Visual 2)*	
		RT (ms)	*Accuracy*	*RT (ms)*	*Accuracy*	*RT (ms)*	*Accuracy*
Affirmative	*Singular*	635 (22)	98.9%	643 (25)	98.2%	-8	0.7%
	Plural	653 (28)	97.7%	627 (25)	98.5%	26	-0.8%
Negative	*Singular*	639 (25)	98.9%	639 (26)	99%	0	-0.1%
	Plural	660 (25)	98.4%	637 (25)	98.8%	23	-0.4%

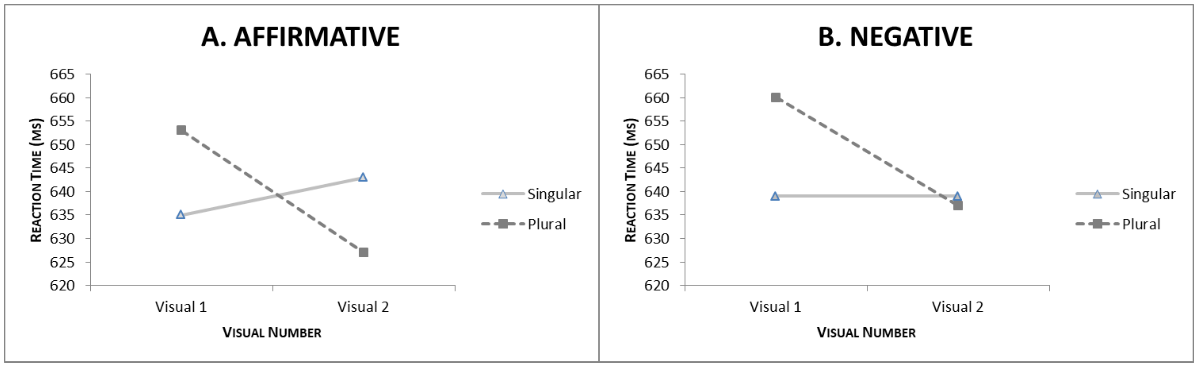

Figure 18: Congruity effect (numerical Stroop interference) of grammatical number and visual numerosity in affirmative (left diagram) and negative (right diagram) sentences in Experiment 5.

4 Discussion

A numerical Stroop interference between grammatical number and visual numerosity (Berent et al., 2005; Patson & Warren, 2010) was observed for singular and plural nouns embedded in affirmative and negative sentences. Plural nouns were easier to count when they were repeated twice on the screen (a visually double condition) than when only one copy was displayed (a visually single condition). For singular nouns this pattern was reversed. It is worth noting that the congruity effect between grammatical number and visual numerosity was considerably larger for plural than for singular nouns. This is consistent with the asymmetry between the treatment of singularity and plurality in language processing uncovered by past psycholinguistic studies (Berent et al., 2005; Bock & Miller, 1991; Pearlmutter et al., 1999).[37]

Crucially, no difference was found for plural nouns in affirmative and negative sentences. The results are inconsistent with the possibility that plural nouns in negative constructions receive an inclusive, number-neutral ("one or more") interpretation immediately when they are encountered. Rather, in negative sentences, the initial number representation seems to be exclusive, which gets reinterpreted at a later stage, perhaps during sentence- or discourse-level information integration. If this interpretation is correct, the results provide support for the idea

[37] The morphological (un)markedness of the critical items was not specifically controlled in this experiment. All plural nouns and most singular nouns were marked with an overt case/number ending.

that language comprehension mechanisms, although geared towards a rapid incremental compositionality, can delay the semantic contribution of some elements, e.g., sentential negation, until a later processing phase, as proposed by the two-step simulation hypothesis of negation processing (Fischler et al., 1983; Kaup et al., 2006; Spychalska, 2011).

CHAPTER VI

COMPOSITIONAL SEMANTICS (QUANTIFIERS)[38]

1 Introduction and chapter overview

Negation is not the only scope taking element in a sentence that can potentially affect the processing of grammatical number. Quantifiers are among the natural language devices used for encoding quantity information alongside grammatical number. They describe relations between sets in the domain of nouns (e.g., *all*, *most*, *much*) and verbs (e.g., *always*, *sometimes*). The results of Experiment 5 (the same Stroop interference for affirmative and negative sentences) indicated that sentential negation did not cancel the initial automatic activation of conceptual plurality associated with plural nouns, even though negation ultimately changes the interpretation of a plural noun from exclusive to inclusive (number neutral). However, negation is not a strictly number-related element. In contrast, quantifiers are more directly linked with conceptual numerosity, so it is possible that they can affect number interpretation faster than negation. Evidence for an interaction between quantification and grammatical number

[38] The experiment presented in this chapter is also described in Gulgowski (2019).

comprehension has been found for a specific type of quantifiers known as distributive (e.g., *each*, *every*). A distributive quantifier assigns an action or quality to each individual member of a plural set separately. This has consequences for the numerical interpretation of nouns in the sentence. Singular nouns in the scope of a distributive operator have been shown to be treated as conceptually plural (Patson & Warren, 2010). One of the open questions is whether the conceptual plurality associated with a singular noun in a quantified expression comes from distributing over multiple events or distributing over multiple objects.

Studying the way in which distributive quantifiers affect the numerical representation of the entities denoted by a noun should provide more information about how grammatical number information is compositionally integrated with the wider logical structure of a sentence. In Experiment 6, distributive-over-events (iterative) expressions were contrasted with distributive-over-objects and collective expressions. The technique was based on a numerical Stroop interference elicited in a word counting task.

The present chapter introduces the topic of distributive and collective quantification. Available evidence for an interaction between distributivity and grammatical number comprehension is discussed. This is followed by the presentation of the chosen methodology, research question and predictions. After that, the description of the experimental design (with materials and procedure), data analysis and results are presented. The chapter ends with the summary and discussion.

2 Background: Distributivity

Sentences with plural arguments often have two or more possible readings.

(30) <u>*Three students*</u> *lifted a piano.*

A ***collective reading*** arises when the plural argument is understood as referring to the group as a whole. Under a collective reading, sentence (30) may be used to describe a situation where three students acted together (as a group) to lift a piano. The students cooperated and none of them was singlehandedly responsible for accomplishing the task. A ***distributive reading*** depends on highlighting the individual constituents (members, parts, etc.) of the plurality. Under this interpretation, sentence (30) can be truthfully uttered if each of the three (exceptionally strong) students managed to lift a piano (potentially the same, although not necessarily).[39]

The issue of distributivity traditionally attracted a lot of attention from formal and theoretical linguists (Champollion, 2010, 2015; Dowty, 1987; Scha, 1984; Tunstall, 1998), but it also offers topics of interest for psycholinguistics. In particular, a distributive reading may present comprehenders with a cognitive challenge. Under a distributive reading, sentence (31) entails the existence of three different cookies. This conceptual plurality has to be reconciled with the grammatical singularity of the object noun phrase.

(31) *Three children ate a cookie.*

A relevant question is whether language users include this information in the mental representations they create when comprehending such sentences. Results of the study by Humphreys & Bock (2005) suggest that this is the case. The authors used prepositional phrases modifying a singular noun to bias participants towards either a collective or distributive interpretation in a sentence completion experiment. The critical words in this experiment were collective nouns (e.g., *gang*). When the following phrase suggested a spatially distributed group (*A gang on the motorcycles…*), participants provided more plural agreement continuations than when the phrase suggested that the group was gathered in one place (*A gang near the motorcycles…*). This outcome shows that other elements in the sentence (a prepositional phrase, in this case) can affect the numerical representation of a noun's referent. However, participants in that study encountered first the singular noun and then the prepositional phrase making the whole expression either distributive or collective. The

[39] A third possible reading is argued to exist for sentences with more than one plural argument.

(i) *Three professors corrected twenty term papers.*

In addition to the distributive reading (each of the three professors corrected a different set of twenty papers) and the collective reading (the professors evaluated every paper together) it is possible that one of the professors was more diligent than her colleagues and corrected twelve papers while the other two corrected together only eight. Still, between them they managed to correct twenty term papers overall. This interpretation is known as a cumulative reading (Scha, 1984; Sternefeld, 1998; Ussery, 1998; Winter, 2000). Cumulative reading depends on dividing the plural set denoted by a noun into sub-groups.

(re)interpretation of the noun was, therefore, always retroactive, which makes any conclusions regarding the timing problematic. Additionally, it is not clear how well the results generalize from collective nouns to more common non-collective words.

A measure of the numerical interpretation of ordinary singular nouns in the scope of a distributive operator has been provided by Patson and Warren (2010). As already discussed briefly in Section 6.1 of Chapter I, the authors used a numerical Stroop interference technique based on a method described previously in Berent et al. (2005). Participants read sentences displayed in one- or two-word chunks. Their task was to count the number of words in the final chunk of each sentence. The final chunk of critical sentences was always one word, while for fillers it was always two words. In the first experiment, the manipulation involved grammatical number. The critical noun was either plural or singular. The results showed that plural nouns were significantly more difficult (longer response times) to recognize as visually single than singular nouns. In the second experiment, the manipulation concerned distributivity. The critical noun was always singular and it was placed in the scope of either a distributive (e.g., ***Each of*** *the men carried a* <u>*box*</u>) or collective operator (e.g., ***Together*** *the men carried a* <u>*box*</u>). The participants took longer to decide that there was one word on the screen when the noun was in a distributive expression than when it was in a collective expression. The results provided evidence that a singular noun in the scope of a distributive quantifier can be construed by the comprehenders as having a plural meaning, which can lead to a conflict between the visual (one word) and conceptual (multiple objects) information in the counting task. The results suggest also that assigning a distributivity-induced plural meaning to a singular noun happens relatively early during the comprehension process.

The source of the conceptual plurality of a singular noun in a distributive context is not fully clear. Participants may interpret the singular noun as conceptually plural because they assume the existence of many different objects denoted by the noun (e.g., several boxes, each brought by a different man). Alternatively, the concept of plurality associated with a singular noun may originate from multiple events.[40] Even if the same object is involved in all events, the

[40] Event semantics has been used to account for distributivity by, for instance, Tunstall (1998), who argues that the English distributive quantifiers *each* and *every* involve a reference to "distributive event structures" (p. 90) and, in effect, characterize multiple (sub)events. A further discussion of event distributivity can be found in,

comprehenders may count its instances (e.g., the same box at different moments, different uses of the same box, etc.).

3 Experiment 6

3.1 Method

The technique used in Experiment 6 was once again based on the numerical Stroop interference (see Section 6.1 of Chapter I for more details).

3.2 Research question and predictions

To determine whether a plural interpretation of a singular noun may be caused by event plurality, three different types of expressions were contrasted: collective, distributive over objects (henceforth called simply "distributive") and distributive over events (henceforth "iterative"). Each type is illustrated by sentences (32)-(34) below.

(32) *Robotnicy wspólnie przenieśli pudło.* [**Collective:** one object, one event]
workers together carried box
'The workers carried the box together'

(33) *Każdy robotnik przeniósł pudło.* [**Distributive:** many objects, many events]
each worker carried box
'Each of the workers carried the box'

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among others, Cable (2014), Krifka (1990), Landman (2000) and Oh (2005). For a discussion of pluractionality (verbal number), see, for instance, Durie (1986), Corbett (2000) and Hofherr (2010).

(34) *Robotnik* *kilkakrotnie* *przeniósł* *pudło.* [**Iterative:** one object, many events][41]
worker several_times carried box
'The worker carried the box several times'

Sentences (32) and (33) correspond to the stimuli used in Patson & Warren (2010). Sentence (32) is disambiguated towards a purely collective reading by the word *wspólnie* 'together', so there is no reason to assume that the singular noun at the end refers to more than one box. Sentence (33), because of the distributive force of the quantifier *każdy* 'each', strongly implies the existence of several different boxes possibly involved in several box-carrying events. Sentence (34), in contrast to sentence (33), is likely to be interpreted as referring to just one box which is involved in multiple box-carrying events.

Assuming that an effect of distributivity in comprehension observed by Patson & Warren (2010) can be replicated in Polish, participants should take significantly more time to decide that one singular noun is on the screen in distributive expressions (sentence (33)) compared to collective expressions (sentence (32)), as the distributivity-induced conceptual plurality of the noun should create an incongruous stimulus (visual singularity vs. conceptual plurality). If the effect can be created by event plurality alone, iterative expressions (sentence (34)) should pattern like distributives, because in both cases the singular noun would be associated with a plural meaning. If, on the other hand, event plurality is not enough to bring about a plural interpretation of a grammatically singular noun, iteratives should pattern like collectives.

3.3 Design

3.3.1 Materials

One hundred and eighty critical sentences were used in the study:

[41] A potential problem with these examples is that they have more interpretations than indicated in the brackets. For instance, sentence (33) can be felicitous in a scenario where there is one object involved in many carrying events. Similarly, sentence (34) does not exclude a situation in which a worker carried different boxes (on different occasions). However, the interpretations in the brackets seem dominant and all other readings require effort or special context.

- 60 sentences with the collective operator *wspólnie* 'together' (e.g., *Robotnicy wspólnie przenieśli pudło/pudła* 'Together the workers carried the box/boxes')
- 60 sentences with the distributive operator *każdy* 'each' (e.g., *Każdy robotnik przeniósł pudło/pudła* 'Each worker carried the box/boxes')
- 60 sentences with the iterative operator *kilkakrotnie* 'several times' (e.g., *Robotnik kilkakrotnie przeniósł pudło/pudła* 'The worker carried the box/boxes several times')

Half of the critical sentences (30 of each type) ended with a singular noun (e.g. *pudło* 'box') and the other half ended with a plural noun (e.g., *pudła* 'boxes').

One hundred and eighty more sentences were added as fillers necessary for the counting task (see the procedure description below), including sentences taken from a different experiment, representing three types of generic expressions:

- 90 sentences corresponding closely in length and structure to the critical sentences
- 30 generic sentences with the quantifier *każdy* 'each' (e.g., *Każdy słoń ma trąbę* 'Each elephant has a trunk')
- 30 generic sentences with the quantifier *wszystkie* 'all' (e.g., *Wszystkie słonie mają trąbę* 'All elephants have a trunk')
- 30 generic sentences without any quantifier (e.g., *Słoń ma trąbę* 'The elephant has a trunk')

Again, exactly half of the fillers ended with a singular noun (e.g., *trąbę* 'trunk') and the other half ended with a plural noun (e.g., *pasy* 'stripes').

This choice of items resulted in 360 trials (180 critical sentences and 180 filler sentences). Half of them ended with a singular noun and the other half with a plural noun. The presentation order was fully randomized for each participant.

3.3.2 Procedure

The procedure was based on the experiment design described in Patson & Warren (2010). Each sentence was introduced by a fixation cross, which remained on the screen for 300 ms. Sentences were presented in one- or two-word chunks displayed at the center of the screen.

Participants moved to the next chunk by pressing the space bar. The last chunk was always displayed with blue font. Participants were instructed to decide how many blue font words they see on the screen at the end of each sentence by pressing left arrow ("one word") or right arrow ("two words"). The blue item(s) remained on the screen until the participant responded with the left or right arrow key.

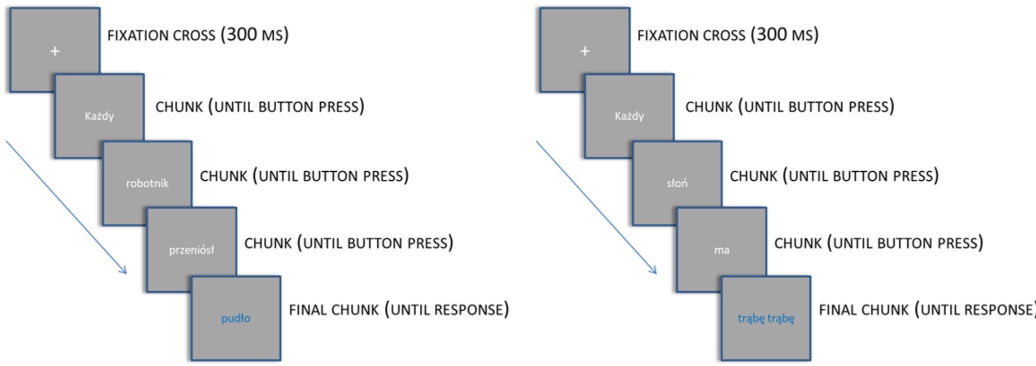

Figure 19: The structure of a trial in Experiment 6 in the visually single (critical trials) and visually double (fillers) condition.

In all critical sentences, the last (blue) fragment was always a single word (e.g., pudło 'box'), so the expected response was "one word". In all filler sentences (generic and non-generic) the blue fragment was the same word repeated twice (e.g., trąbę trąbę 'trunk trunk').

Thirty critical sentences and 18 fillers were followed by a comprehension question displayed in green font, with two possible answers displayed below the question on the left and right side of the screen. The participants indicated their choice by pressing the left or right arrow key.

The experiment proper was preceded by a training session consisting of 14 sentences with four comprehension questions. After every counting and comprehension decision, there was a 1000 ms feedback informing the participant whether the answer was correct or incorrect. During the experiment proper a feedback was displayed after a counting decision only when it was incorrect. The training session ended with a message informing about the number of correct and incorrect responses. No training item appeared later in the experiment proper.

Twice during the experiment (after every 120 trials) there was a message informing about a break time. The participant could proceed when ready by pressing the space bar.

The experiment was designed and presented using the PsychoPy software (version 1.83.03) (Peirce, 2007, 2009).

3.3.3 Participants

Thirty-one students of the Institute for English Studies of the University of Wrocław (7 men) took part in the experiment. Participants were all native speakers of Polish. Average age was 20 (*SD*=2.47).

3.4 Results: Reaction Times

The data were cleaned first by removing all incorrect trials and then by eliminating all trials with reaction times (RT) 2 standard deviations above and below the mean in each condition for every participant. This resulted in removing 279 data points, which constituted approximately 5% of correct trials. The remaining data were subjected to tests performed with the SPSS software (Version 22).

In order to determine the interpretation of a singular noun in the scope of different operators, a 3×2 ANOVA was conducted with RT as the dependent variable and the following independent factors:

- Expression Type (collective, distributive, iterative)
- Grammatical Number (singular, plural)

In purely numerical terms, there was a trend in the data consistent with the effect of distributivity in comprehension reported by Patson & Warren (2010). Participants were slightly faster to identify singular nouns as visually single in the collective condition (596 ms) than in the distributive condition (603 ms). Within the collective condition, responses to singulars were faster than to plurals and the pattern was opposite within the distributive condition. Responses to singulars in the iterative condition fell between the other two conditions (598 ms). Within the iterative condition, responses to singulars were faster than to plurals, which made iterative expressions closer to collective than to distributive expressions (Figure 20).

Unfortunately, this trend was not supported by the statistical analysis. There was no main effect of Expression Type ($F_1(2,60)=0.08$ $p=.926$; $F_2(2,174)=0.10$ $p=.904$) and no main effect of Grammatical Number ($F_1(1,30)=0.34$ p=.565; $F_2(1,174)=0.64$ $p=.424$). The interaction of Expression Type with Grammatical Number also did not reach the level of statistical significance ($F_1(2,60)=0.35$ $p=.709$; $F_2(2,174)=0.40$ $p=.673$).

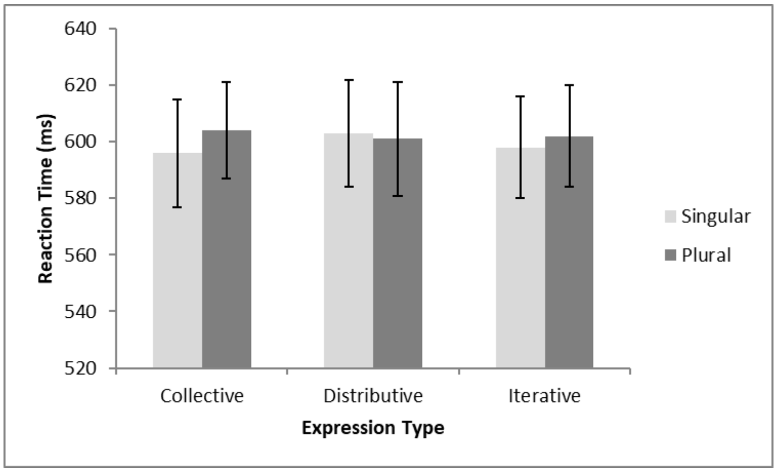

Figure 20: Mean reaction times (ms) in the counting task for singular and plural nouns in collective, distributive and iterative expressions in Experiment 6. The bars represent standard errors.

Table 19: Mean accuracy (percent of correct responses) in the counting task for singular and plural nouns in collective, distributive and iterative expressions in Experiment 6 (standard errors in parentheses).

EXPRESSION TYPE		GRAMMATICAL NUMBER	
		Singular	*Plural*
Collective	*Together the workers…*	99.7% (0.2)	99.0% (0.4)
Distributive	*Each worker…*	99.1% (0.3)	99.1% (0.4)
Iterative	*The worker … several times*	99.0% (0.3)	98.3% (0.5)

An inspection of the accuracy of responses for comprehension questions in each condition indicated that participants were attentive and had no problems with understanding the sentences (over 90% of correct answers in all conditions).

4 Discussion

The experiment failed to replicate for Polish the influence of a distributive quantifier on the conceptual representation of singular nouns in a Stroop-interference counting task found previously for English (Patson & Warren, 2010). The participants were predicted to be faster to recognize that only one singular noun was present on the screen when the noun occurred in a collective expression than in a distributive expression. Although a trend towards this result was indeed observed, the difference was not statistically significant. Due to the lack of any statistically significant result, it was also impossible to answer the main research question concerning the numerical interpretation of singular nouns in expressions distributive over events (iterative).

One possible explanation for the discrepancy between the results of the present experiment and that of Patson & Warren (2010) might be morphophonological differences. Whereas singular nouns used by Patson and Warren (2010) had (like basically all singular nouns in English) no overt number marking, almost all singular forms used in the present experiment had a case/number suffix (e.g., *piłk-ę* 'ball-ACC.SG').[42] Experiment 3 demonstrated an effect of morphological markedness on grammatical number processing. It is possible that the strong visual cue for grammatical singularity made it more difficult to think of the noun's referent in terms of multiple objects, even when the context favored this interpretation. This may have masked any possible effect of distributivity or iterativity.

One could also look to formal semantics for a possible explanation of the null results in the present experiment. The standard formalizations of collective and distributive meanings in the theoretical literature (e.g., Champollion, 2015, 2016) may suggest that it is not the semantics of the object noun phrase which contributes the plurality inference in distributive expressions, but instead the source of the inference is the whole construction (or its logical structure). No effect should, therefore, be expected on the object itself. However, formal descriptions are not typically developed as models of psychological processes associated with language

[42] There were only two exceptions (*wynalazek* 'discovery' and *artykuł* 'article'). See Appendix 1 for a full list of critical sentences used in the experiment.

comprehension. It is far from clear how and when the actual processing mechanisms make use of the information afforded by logical scope-taking operators. The timing may in fact differ depending on the type of the logical element. The results of Experiment 5 provided some evidence that the interpretation of sentential negation is delayed until the sentence is complete, which is consistent with past psycholinguistic research discussed in Section 2.2 of Chapter V (Fischler et al., 1983; Lüdtke et al., 2008). On the other hand, the results of Patson & Warren (2010) suggest that quantifiers may exert an influence on the interpretation of a singular noun quite early, perhaps immediately after a successful recognition of the word.

CHAPTER VII

GENERAL DISCUSSION AND CONCLUSIONS

1 Introduction and chapter overview

The six psycholinguistic experiments presented above were designed and conducted to learn more about the aspects of grammatical number processing that have received so far relatively little attention: the early extraction of numerical information from singular and plural nouns and the integration of this information with context. Three areas were investigated: form-meaning mismatches, morphological markedness and compositional semantics. Research problems within each area were addressed using experimental techniques based on interference phenomena well documented in the literature on numerical cognition but seldom applied to study grammatical number in language. The final chapter of the thesis summarizes the main results for each area and discusses their significance before moving on to methodological conclusions and then to possible directions for future investigations.

2 Findings

The data obtained in the experiments were used to test specific research hypotheses associated with each of the three areas of investigation. The present section brings together the main findings in the form of a summary and a discussion of their implications for models of grammatical number processing. Problematic issues and conflicting outcomes are addressed.

2.1 Form-meaning conflict

Sometimes a conflict arises between the value of a word's grammatical number and its lexical meaning. The number mismatch constitutes a potential challenge for language comprehenders, as they have to reconcile the two sources of information. How is the mismatch processed?

Words with a number mismatch were investigated in Experiment 1, Experiment 2 and Experiment 4. The items under investigation included collective nouns, mass nouns and *pluralia tantum*. The data obtained in those experiments suggest that such words initially activate numerical concepts consistent with their grammatical number, even if ultimately the number interpretation is different.

Experiment 1 provided the most clear results. The experiment used a semantic-number judgment task intended to elicit a SNARC effect and a size congruity effect for collective and non-collective (unitary) nouns. No evidence for an SCE was found, but a SNARC effect was evident in the data, revealing that collective singulars behaved like unitary singulars. Both singular noun classes received significantly faster responses with the left hand than with the right hand. In this respect, both singular groups clearly differed from plurals, which were responded to faster with the right hand. This pattern of results for singular and plural nouns resembles the SNARC effect observed in numerous studies for small and large numbers (Dehaene et al., 1993; Gevers et al., 2006; Göbel et al., 2011) and replicates in Polish the findings for grammatical number in German (Röttger & Domahs, 2015). The similarity between collective and unitary singulars is in line with the results from past research. In studies on agreement attraction, collective and non-collective singulars behaved similarly in that both singular classes were unable to disrupt agreement computation in contrast to morphologically plural nouns (Bock et al., 2001; Bock & Eberhard, 1993). The results of Experiment 1 provided support for the hypothesis that collective singulars are conceptualized primarily as referring to a single entity (in accordance with their grammatical number), with individual constituents highlighted through a pragmatic mechanism if contextually appropriate.

Experiment 2 modified the design of Experiment 1 to increase the likelihood of finding a significant SCE. Unfortunately, it failed to produce any statistically valid effect, either in terms of the SNARC effect or the SCE.

In Experiment 4, the SNARC-SCE method was replaced by a word counting task intended to elicit a numerical Stroop effect. Collective singular nouns and mass nouns (grammatically singular, conceptually unspecified) did not differ significantly from ordinary countable singular nouns in terms of the Stroop interference. However, because of an unexpected interaction of the morphological markedness with the visual number (see the next section), any interpretation of this result is problematic. Similarly, *pluralia tantum* nouns (grammatically plural, conceptually ambiguous) did not differ significantly from ordinary countable plural nouns. However the reliability of this result is, once again, questionable because nouns in these conditions showed very little congruity effect (the difference between the visually single and visually double display). Overall, the results of Experiment 4 provided some support for the possibility that the early activation of numerical concepts is driven primarily by the grammatical number of the word with no regard for the lexical specification, but this conclusion is weakened by the problems mentioned above.

2.2 Morphological markedness

During language comprehension, a proper activation of the numerical concepts depends usually on the correct recognition of the number form. For instance, in English number is marked morphologically as an overt affix on plural nouns (e.g., *dog-s*) and a zero-ending on singular nouns (e.g., *dog-Ø*). This is a typical pattern observed across natural languages. If a language distinguishes singular and plural number values, plural forms are typically marked, while singular forms tend to be unmarked (Greenberg, 1963, Universal 35). It can be assumed that this contrast has consequences for the processing of grammatical number. Indeed, evidence for an asymmetry between the treatment of singularity and plurality in language processing has been uncovered by past psycholinguistic studies (Berent et al., 2005; Bock & Miller, 1991; Pearlmutter et al., 1999). It is possible that words that are overtly marked for number have a stronger association with a specific numerical interpretation, while the unmarked forms are not linked with a specific number concept or the link is weaker. Past experiments have largely been based on materials and language users representing languages like English, where almost all singular nouns are morphologically unmarked and most plural nouns have an overt ending. It is unclear whether the processing differences observed in past studies were caused by the contrast in morphological marking or by the fact that one of the number values is inherently easier to process than the other. Polish, on the other hand, offers both marked and unmarked singular forms (e.g., *małp-a* 'monkey-NOM.SG' vs. *kot-Ø* 'cat-NOM.SG') in addition to marked plurals. This allows for a direct comparison of the influence of overt and zero morphology on the numerical interpretation of singular nouns.

The possible difference in the processing of overtly marked and unmarked singular nouns was investigated in Experiment 3 and Experiment 4. Both experiments addressed this issue using a word counting task intended to elicit a numerical Stroop effect. The two experiments provided mixed results.

Experiment 3 used ordinary countable singular and plural nouns. Singular nouns selected for the experiment belonged to two different types: those encoding singular number through an overt suffix (marked) and those with no number ending (unmarked). The results indicated that the strength of the numerical Stroop interference between grammatical number and visual numerosity depended on the presence of an overt morphological marker. Morphologically marked singulars gave rise to a bigger congruity effect than unmarked singulars. In the first study that used the Stroop effect for examining grammatical number processing (Berent et al., 2005), grammatically singular Hebrew nouns did not produce any interference with the visual number in a counting task, suggesting that they did not evoke a specific number interpretation. However, singular nouns in that study were unmarked. The outcome of Experiment 3 in the present work suggests that singular nouns are more likely to evoke a specific numerical concept ("exactly one") if they are clearly marked morphologically. This is in line with the results of Eberhard (1997).

Experiment 4 had two main research goals. It was designed to investigate further the processing of overt singular morphology and to test the processing of nouns with a conflict between the grammatical number and the lexical number (see the previous section). In addition to ordinary countable singular nouns, the materials in the experiment included also collective singulars and mass nouns. When those three groups of grammatically singular nouns were analyzed together, an expected Stroop congruity was found only for morphologically unmarked singulars, contradicting the findings of Experiment 3. It is unclear how to account for this difference. One possibility is that the introduction of several types of nouns in Experiment 4 (including nouns with a form-meaning conflict) affected the performance of participants, drawing their attention to the problem with mapping from grammatical to conceptual number. This may have disrupted the process of automatic extraction of number values, especially from overtly marked forms.

2.3 Compositional semantics

Sometimes the intended number interpretation of nominal phrases is based only partly on the form of the noun itself. Additional numerical cues in a sentence can be provided through quantificational elements, including numerals, determiners, quantifiers and adverbs. Number interpretation may also depend on the type of utterance and its logical structure (e.g., negative vs. affirmative sentences). A question relevant for the research on number processing is at which processing stage context starts interacting with the numerical interpretation of a noun.

The influence of different scope-taking operators on the early numerical interpretation of singular and plural nouns was investigated in Experiment 5 and Experiment 6.

2.3.1 Negation

Plural nouns occurring in questions, conditional constructions and, most notably, negative sentences are typically understood as referring not to a group of individuals (the exclusive "two or more" interpretation), but to any number of individuals (the inclusive "one or more" interpretation). Past research provided evidence suggesting that negation may be integrated with the meaning of the entire expression after some delay. This is known as the two-step simulation hypothesis of negation processing (Fischler et al., 1983; Kaup et al., 2006; Lüdtke et al., 2008; Spychalska, 2011). According to the hypothesis, the meaning of a negative sentence is constructed first as if ignoring the negative element, while the correct negative interpretation is built at a later stage. As a result, sentences *A robin is a bird* and *A robin is not a bird* are initially equivalent in terms of the mental models created by comprehenders. If negative processing proceeds in such a manner, it is possible that a plural noun in a negative expression receives initially an exclusive reading (consistent with the affirmative proposition), which is later replaced by an inclusive interpretation (consistent with the negative proposition).

This possibility was investigated in Experiment 5 using a word counting task intended to elicit the numerical Stroop effect. Singular and plural nouns were presented in affirmative and negative sentences. Plural nouns in both types of sentence gave rise to a similar numerical Stroop effect (faster responses when they were repeated twice on the screen than when only one copy was displayed). The results aligned with the predictions of the two-step simulation hypothesis. Plural nouns in negative constructions did not seem to receive an inclusive ("one or more") interpretation immediately when they were encountered, because this reading is essentially number neutral and thus would not have led to a numerical Stroop interference. Rather, the initial interpretation of plural nouns in negative sentences was exclusive, with a reinterpretation occurring at a later stage, possibly during sentence- or discourse-level information integration. Within a wider discussion of incrementality in language comprehension (Boland et al., 1990; Frazier, 1987; Tanenhaus et al., 1995), this result provides support for the idea that language comprehension mechanisms can delay the semantic contribution of at least some elements, e.g., sentential negation, until a later processing phase, as proposed by accounts like the two-step simulation hypothesis.

2.3.2 Quantifiers

Negation is not the only sentence element with a potential to affect the numerical interpretation of a noun. A numerical reading can also depend on the presence of quantifiers. Quantifiers establish relations between sets and so are more directly related to conceptual numerosity than negation. Consequently, it is possible that they affect number interpretation earlier. An early interaction between quantification and grammatical number comprehension has been found for distributive quantifiers (e.g., *each*, *every*) taking scope over singular nouns. Distributive quantifiers assign an action or quality to each individual member of a plural set separately. Singular nouns in the scope of a distributive operator (e.g., the word *box* in the sentence *Every man carried a box*) have been shown to be treated as conceptually plural (Patson & Warren, 2010). However, distributive expressions of this type entail the existence of not only many objects but also many situations involving those objects. It is unclear whether the conceptual plurality associated with a singular noun in a quantified expression comes from distributing over multiple events or distributing over multiple entities.

This issue was addressed in Experiment 6 using a word counting task intended to elicit the numerical Stroop effect. Singular and plural nouns were presented in three types of quantified expressions: collective, distributive over objects and distributive over events (iterative). Unfortunately, the experiment did not produce conclusive results. It failed to replicate for Polish the effect of a distributive quantifier on the conceptual representation of singular nouns found for English by Patson & Warren (2010). Although a trend consistent with the results of that study was observed, the differences between conditions did not achieve statistical significance. This made it impossible to answer the main research question concerning the interpretation of singular nouns in iterative expressions with pure event distributivity.

2.4 Findings: Conclusions

The picture emerging from the experiments is incomplete due to the issues with some of the results described above and the inherent limitation of the chosen method (e.g., no access to a precise timing of the mental processes). Furthermore, the experiments were conducted with native speakers of Polish and it is unclear how well the results generalize to other languages. This being said, some tentative conclusions for models of grammatical number processing can be offered.

To begin with, comprehenders expect grammatical number to be a reliable cue for the numerosity of the objects under discussion. The grammatical number value seems to be identified automatically since it leads to an interference even if it is irrelevant for performing a given task (e.g., counting words on the screen). The grammatical number information consistently activates numerical concepts: grammatically singular nouns evoke conceptual singularity and grammatically plural nouns activate conceptual plurality. This happens even if the lexical specification of a noun is at odds with its morphosyntactic marking, as is the case with collective singular nouns, mass nouns and *pluralia tantum*. The initial representation of the numerosity of the denoted objects is also unaffected by at least some compositional processes. Specifically, sentential negation has no impact on the early extraction of the number value, even though it affects the numerical interpretation of the entire expression.

This independence from lexical and compositional factors suggests that the extraction of grammatical number information happens soon after a noun is encountered, possibly before or in parallel to the lexical semantics. This may follow from the status of number as a grammatical category involved in agreement processes. Electrophysiological studies show the separability of semantic and morphosyntactic processes in the form of separate early ERP components,[43] with signs of interaction between the two types of information visible in relatively late time windows (Friederici, 2002). Effects of semantic manipulations are commonly observed as amplitude modulations of N400, which is a component peaking around 400 ms after stimulus onset (Kutas & Federmeier, 2011). Processes that require access to the syntactic category of a word are reflected in the amplitude of eLAN, an early component peaking around 150-300 ms after stimulus onset (Hahne & Friederici, 1999), which has been found for word-category violations even in meaningless “jabberwocky” sentences (Hahne & Jescheniak, 2001). Finally, manipulations involving grammatical number affect the amplitude of LAN, a component peaking around the same time as N400 (Barber & Carreiras, 2005; Lück et al., 2006). In a study investigating grammatical gender[44] (Gunter et al., 2000), gender agreement violations

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[43] ERP (event-related potentials) components are changes in the electric potentials registered at electrodes attached to the scalp. The signal is time-locked to a specific stimulus (e.g., a syntactically or semantically anomalous word) and the potential changes are assumed to represent brain activity in response to the stimulus. ERP components are classified according to their polarity (a negative or positive deflection), peak time and electrode location. Those parameters can be reflected in the name of a component. For example, N400 is a negative going change peaking around 400 ms after stimulus onset and LAN stands for “left anterior negativity”. For more information see Bornkessel-Schlesewsky & Schlesewsky (2009), Kaan (2007) or Luck (2005).

[44] Gender resembles number in being another nominal grammatical category that participates in agreement and is (partially) interpretable. ERP studies show that number and gender behave in a similar way and both differ from the category of person with respect to, e.g., the P600 component (Nevins et al., 2007; Zawiszewski et al., 2015).

elicited a LAN effect, while manipulating the cloze probability of words (a lexical factor) elicited an N400 effect. Both effects were independent of each other. Agreement violations and cloze probability interacted only in the P600 time window. Thus ERP evidence points to lexical and grammatical information being processed independently and in parallel at an early stage of comprehension. Additionally, as discussed in Section 2.2 of Chapter V, the N400 component is unaffected by sentential negation (Fischler et al., 1983; Lüdtke et al., 2008). It is unclear how soon exactly grammatical number becomes available for the language processing system, but being a grammatical category expressed through a case/number morpheme it may become available independently of the lexical semantics of a noun. This would be consistent with the findings of the present thesis. The contribution of the present work lies in the fact that the studies mentioned above used mostly agreement or morphological violations to investigate grammatical number processing, whereas the experiments described here used techniques sensitive to number semantics. Additionally, the present experiments suggest that the automatic extraction of a number value may be facilitated by the presence of an overt number ending in contrast to zero-marked forms.

The conceptual representations of number built during language comprehension seem to rely, at least partially, on the numerical cognition responsible for dealing with all kinds of quantities (Feigenson, Dehaene, & Spelke, 2004). The processing of grammatical number resembles the processing of numbers in general in at least two ways. First, the singularity or plurality of nouns interferes with the assessment of the visual numerosity of stimuli during a counting task, giving rise to an interference akin to the Stroop effect found for counting repeated digits (*7*) or numerals (*seven*) (Flowers, Warner & Polansky 1979; Naparstek & Henik 2010; Pavese & Umiltà 1998; Windes 1968). Second, grammatical number processing apparently makes use of the space-number connection reported in the literature on numerical cognition in the form of the SNARC effect (Dehaene et al., 1993). Singular nouns are linked with the left response side, while plural nouns show affinity with the right response side (at least for Polish comprehenders familiar with the left-to-right reading direction). This implies the organization of linguistic number concepts on a mental number line, with single entities on the left end and groups on the right end, in a manner reminiscent of the organization of other quantity-related concepts (Dehaene et al., 1993; Göbel et al., 2011; Pavese & Umiltà, 1998). The present work replicated for Polish the results of past experiments linking grammatical number processing with numerical cognition for Hebrew, English and German (Berent et al., 2005; Patson & Warren, 2010; Röttger & Domahs, 2015). One of the goals of this work was also to look for signs of a size congruity effect related to grammatical number (and collectivity), but the results provided no evidence that linguistic number representations can interfere with the discrimination of visual size. In contrast, non-grammatical quantities give rise to the size congruity effect (Besner & Coltheart, 1979; Cohen Kadosh et al., 2007; Foltz et al., 1984; Henik & Tzelgov, 1982). This points to the possible limitations of the mental simulations that can be constructed based on a grammatical category like number.

3 Methodology

The methods chosen for the experiments were based on three interference phenomena well documented in the literature on numerical cognition: the numerical Stroop effect, the SNARC effect and the size congruity effect. This methodological choice was dictated by the need to use number-meaning diagnostics sensitive to fast and automatic processes of information extraction from stimuli. The present section contains the evaluation of each effect in terms of its effectiveness for investigating the research questions.

3.1 Numerical Stroop effect

The numerical Stroop effect manifests as problems with counting number symbols when their visual numerosity is incongruent with their semantics (e.g., counting the number of *2*s in the sequence *2 2 2 2*) (Flowers, Warner & Polansky 1979; Naparstek & Henik 2010; Pavese & Umiltà 1998; Windes 1968). It was first applied to study grammatical number by Berent et al. (2005), who demonstrated that grammatically plural Hebrew nouns are easier to count when two tokens are on the screen (e.g., *dogs dogs*) than when only one token is displayed (e.g., *dogs*). This result was reproduced in Experiment 3 and Experiment 5 of the present work, with additional evidence suggesting that singular nouns can also lead to an interference if they are properly marked. A lack of clear evidence for the expected interference in Experiment 4 may be the result of using too many different stimulus types, including nouns with a number mismatch (collective nouns, mass nouns, *pluralia tantum*) and non-linguistic shapes (white rectangles). If that is the case, it suggests that the method is sensitive to stimuli composition. Perhaps a series of smaller experiments with fewer conditions is preferable to one bigger experiment.

It should also be noted that the congruity effects (differences between congruous and incongruous conditions) were overall small (3 to 11 ms in Experiment 3 and 4 to 24 ms in Experiment 5). The numerical Stroop effect is a variant of the classic color-name interference, which is a very robust effect replicated countless times (Jensen & Rohwer, 1966; MacLeod, 1991; Stroop, 1935). However, the relation between the visual and semantic dimensions for counting singular and plural nouns is less direct than for determining the color of color words in a traditional Stroop experiment. Consequently, the effect may be weaker or more sensitive to specific conditions. More studies are needed to fully determine the limitations of the technique.

3.2 SNARC effect

The SNARC effect has been observed for number-related tasks (e.g., parity judgments) and consists of response facilitation for small numbers when responding with the left hand and for big numbers when responding with the right hand (Dehaene et al., 1993). It was applied to study grammatical number by Röttger & Domahs (2015), who demonstrated that grammatically singular nouns receive faster responses with the left hand and grammatically plural nouns receive faster responses with the right hand. This result was replicated in Experiment 1, with additional evidence suggesting that collective singular nouns (semantically ambiguous between singularity and plurality of denoted objects) pattern with ordinary singular nouns. A failure to obtain the effect in Experiment 2 is likely related to the difference in experimental tasks between the two experiments. Whereas in Experiment 1 the task required deliberate focus on conceptual number (“Does the word name one or more than one thing?”), in Experiment 2 participants were asked to focus on grammatical number (“Is this word singular or plural?”). Although the SNARC effect has been found previously also for tasks where numerosity was not attended (Fitousi et al., 2009; Keus & Schwarz, 2005), the results of Röttger & Domahs (2015) suggest that the hand-number interference emerges fully for grammatical number only when the stimuli are processed “deep” enough (as discussed in Section 6.2 of Chapter I, the effect was statistically significant only for the task requiring direct access to number semantics, i.e., deciding whether a given noun names one or more than one entity, but not for tasks requiring access to the visual features, lexical status or animacy semantics of the word). The contrast between Experiment 1 and Experiment 2 in the present work is consistent with this possibility. SNARC is, therefore, a promising tool for future studies of grammatical number processing, although it requires a careful selection of the experimental task.

3.3 Size congruity effect

The size congruity effect has been observed in size and magnitude comparison tasks. In its numerical variant, it manifests as problems with comparing two numbers if their semantic magnitudes are incongruent with their visual sizes (e.g., **3** vs. 5) (Henik & Tzelgov, 1982). It had not been applied to study grammatical number before (at least no published results could be found). It was chosen for Experiment 1 and Experiment 2 in the present work as a possible number interpretation diagnostic, because it is plausible that a word associated with a conceptual plurality could be congruent with big size and incongruent with small size and the opposite could hold for a word associated with a conceptual singularity (a group is typically bigger than an individual). Unfortunately, no statistically reliable evidence for this effect was found. One possible explanation is that numerical concepts activated during language comprehension are not detailed enough to provide information about size differences. Another possibility is that the failure to obtain an SCE lies in the design of the experiments. In particular, the stimuli were not strictly controlled for the sizes of the objects they denote. Given that a semantic size has been demonstrated to interfere with the visual size of the stimuli in the classic variant of the SCE (Paivio, 1975), this could have been a confound masking any possible effect in the present experiments.

3.4 Methodology: Conclusions

The experiments validated the Stroop effect and the SNARC effect as useful for studying the processing of grammatical number in language by replicating some of the results of the previous studies (Berent et al., 2005; Patson & Warren, 2010; Röttger & Domahs, 2015) and extended the use of those two effects by applying them to investigate new research problems in the domain of linguistic number. Both effects are promising tools for future investigations in this field of research. The failure to elicit a size congruity effect may suggest that the processing of grammatical number during language comprehension is not associated with the processing of size, unlike the processing of non-grammatical number concepts, which have been demonstrated to interfere with the discrimination of quantities like size or luminance (Cohen Kadosh & Henik, 2006). If that is true, then techniques based on SCE would not be suitable for studying grammatical number. However, more attempts using different stimuli is required to verify that this indeed is the case.

4 Future research

One obvious avenue of future research is extending the investigations with interference techniques to languages with richer grammatical number systems. Will dual and trial numbers pattern with singular or with plural nouns in terms of the SNARC effect? How about paucal?

Future studies can focus on establishing a more exact timing of the extraction of number features, resolution of the number mismatch or the integration of number information with the rest of the sentence. For example, Experiment 5 revealed that sentential negation does not change the early numerical interpretation of a plural noun from exclusive (“more than one”) to inclusive (“one or more”). However, the inclusive reading is ultimately computed by the comprehender. How much time is needed for the influence of negation to take effect? A future study with the numerical Stroop interference technique can address this question by introducing a delay between the stimulus display and the response in the counting task. Similarly, a delayed response can help better understand the chronology of building the numerical interpretation for words whose lexically specified number does not match their grammatical number (e.g., collectives like *team*). Moving beyond the interference techniques, an eye tracking study, particularly one using the visual-world paradigm, would be well suited to reveal the timing of arriving at the intended numerical interpretation of a whole phrase or a sentence as it unfolds.

Another direction could be the further exploration of the relation between grammatical number processing and general numerical cognition. This enquiry would benefit greatly from access to powerful neurocognitive tools. Brain imaging devices (fMRI, PET) could reveal the degree of overlapping brain activity for tasks involving grammatical number (e.g., deciding whether a noun is singular or plural) and those involving determining extra-linguistic numerosity (e.g., counting dots on the screen). Magnetic stimulation temporarily disrupting normal functions in specific brain areas (TMS) could be used to stimulate the region involved in numerical processing (middle and inferior parietal lobe) and test the consequences of this operation on the ability to process number information in linguistic stimuli.

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APPENDIX 1

Lists of experimental stimuli.

Experiment 1

#	UNITARY SNG	UNITARY PL
1	*wilk*	*wilki*
2	*tygrys*	*tygrysy*
3	*pies*	*psy*
4	*jeleń*	*jelenie*
5	*baran*	*barany*
6	*górnik*	*górnicy*
7	*kelner*	*kelnerzy*
8	*klient*	*klienci*
9	*krawiec*	*krawcy*
10	*lekarz*	*lekarze*
11	*malarz*	*malarze*
12	*pacjent*	*pacjenci*
13	*polityk*	*politycy*
14	*rolnik*	*rolnicy*
15	*sąsiad*	*sąsiedzi*
16	*kredens*	*kredensy*
17	*fotel*	*fotele*
18	*skuter*	*skutery*
19	*stół*	*stoły*
20	*piec*	*piece*
21	*słup*	*słupy*
22	*mikser*	*miksery*
23	*pędzel*	*pędzle*
24	*rower*	*rowery*
25	*sierp*	*sierpy*
26	*młotek*	*młotki*
27	*kabel*	*kable*
28	*pasek*	*paski*

#	COLLECTIVE SNG	COLLECTIVE PL
1	*ławica*	*śledzie*
2	*wataha*	*dziki*
3	*sekta*	*wyznawcy*
4	*klan*	*ojcowie*
5	*plemię*	*rodacy*
6	*gromada*	*wróble*
7	*dywizja*	*czołgi*
8	*banda*	*zbóje*
9	*brygada*	*saperzy*
10	*stado*	*konie*
11	*kadra*	*urzędnicy*
12	*załoga*	*marynarze*
13	*zbiór*	*obywatele*
14	*armia*	*żołnierze*
15	*ekipa*	*robotnicy*
16	*tłum*	*kibice*
17	*drużyna*	*sportowcy*
18	*rodzina*	*krewni*
19	*grupa*	*studenci*
20	*zespół*	*piłkarze*

29	*silnik*	*silniki*
30	*pojazd*	*pojazdy*

Experiment 2

#	UNITARY SNG	UNITARY PL
1	*koza*	*kozy*
2	*hiena*	*hieny*
3	*puma*	*pumy*
4	*krewny*	*krewni*
5	*dzik*	*dziki*
6	*szczur*	*szczury*
7	*zebra*	*zebry*
8	*bocian*	*bociany*
9	*kupiec*	*kupcy*
10	*świnia*	*świnie*
11	*muzyk*	*muzycy*
12	*malarz*	*malarze*
13	*rolnik*	*rolnicy*
14	*gracz*	*gracze*
15	*wilk*	*wilki*
16	*osioł*	*osły*
17	*lekarz*	*lekarze*
18	*artysta*	*artyści*
19	*górnik*	*górnicy*
20	*owca*	*owce*
21	*kolega*	*koledzy*
22	*małpa*	*małpy*
23	*klient*	*klienci*
24	*ptak*	*ptaki*
25	*bandyta*	*bandyci*
26	*krowa*	*krowy*
27	*matka*	*matki*
28	*żona*	*żony*
29	*siostra*	*siostry*
30	*żyrafa*	*żyrafy*

#	COLLECTIVE SNG	COLLECTIVE PL
1	*ławica*	*ławice*
2	*wataha*	*watahy*
3	*chmara*	*chmary*
4	*sekta*	*sekty*
5	*klan*	*klany*
6	*plemię*	*plemiona*
7	*gromada*	*gromady*
8	*brygada*	*brygady*
9	*banda*	*bandy*
10	*pułk*	*pułki*
11	*stado*	*stada*
12	*sztab*	*sztaby*
13	*kadra*	*kadry*
14	*załoga*	*załogi*
15	*grono*	*grona*
16	*zbiór*	*zbiory*
17	*armia*	*armie*
18	*ekipa*	*ekipy*
19	*naród*	*narody*
20	*kapela*	*kapele*
21	*tłum*	*tłumy*
22	*zgraja*	*zgraje*
23	*drużyna*	*drużyny*
24	*trzoda*	*trzody*
25	*obsada*	*obsady*
26	*bractwo*	*bractwa*
27	*zespół*	*zespoły*
28	*rodzina*	*rodziny*
29	*legion*	*legiony*
30	*eskadra*	*eskadry*

Experiment 3

#	UNMARKED SNG	MARKED PL
1	*sznur*	*sznury*
2	*tygrys*	*tygrysy*
3	*krzak*	*krzaki*
4	*port*	*porty*
5	*katar*	*katary*
6	*dysk*	*dyski*
7	*czołg*	*czołgi*
8	*szewc*	*szewcy*
9	*komar*	*komary*
10	*robak*	*robaki*
11	*rozkaz*	*rozkazy*
12	*kwiat*	*kwiaty*
13	*krawat*	*krawaty*
14	*wilk*	*wilki*
15	*zamach*	*zamachy*
16	*konar*	*konary*
17	*wybryk*	*wybryki*
18	*szpak*	*szpaki*
19	*schron*	*schrony*
20	*brzeg*	*brzegi*
21	*grzyb*	*grzyby*
22	*nakaz*	*nakazy*
23	*borsuk*	*borsuki*
24	*kolos*	*kolosy*
25	*kram*	*kramy*

#	MARKED SNG	MARKED PL
1	*płaca*	*płace*
2	*porcja*	*porcje*
3	*susza*	*susze*
4	*hala*	*hale*
5	*plaża*	*plaże*
6	*róża*	*róże*
7	*mafia*	*mafie*
8	*zorza*	*zorze*
9	*kasza*	*kasze*
10	*kropla*	*krople*
11	*fala*	*fale*
12	*kula*	*kule*
13	*studnia*	*studnie*
14	*burza*	*burze*
15	*lekcja*	*lekcje*
16	*owca*	*owce*
17	*iluzja*	*iluzje*
18	*szala*	*szale*
19	*pralnia*	*pralnie*
20	*stacja*	*stacje*
21	*racja*	*racje*
22	*wieża*	*wieże*
23	*wiśnia*	*wiśnie*
24	*loża*	*loże*
25	*tafla*	*tafle*

Experiment 4

#	COUNT SNG	PL
1	*wiertło*	*noże*
2	*dłuto*	*kable*
3	*wiosło*	*kosze*
4	*miotła*	*paski*
5	*kosa*	*opony*
6	*skrzydło*	*silniki*
7	*lustro*	*klucze*
8	*piła*	*samoloty*
9	*łóżko*	*pojazdy*
10	*okno*	*autobusy*
11	*antylopa*	*lisy*
12	*łasica*	*motyle*
13	*hiena*	*mrówki*
14	*zebra*	*węże*
15	*czapla*	*szczury*
16	*świnia*	*owady*
17	*krowa*	*gołębie*
18	*wrona*	*koty*
19	*mucha*	*myszy*
20	*ryba*	*konie*
21	*pilnik*	*sierpy*
22	*mikser*	*łomy*
23	*skuter*	*młotki*
24	*kran*	*donice*
25	*pędzel*	*pionki*
26	*fotel*	*widelce*
27	*statek*	*wraki*
28	*rower*	*ołówki*
29	*stół*	*pręty*
30	*komputer*	*kredki*
31	*aligator*	*drozdy*
32	*borsuk*	*gawrony*
33	*żółw*	*żuki*

#	MASS SNG
1	*wata*
2	*tworzywo*
3	*wapno*
4	*żyto*
5	*złoto*
6	*mięso*
7	*błoto*
8	*szkło*
9	*drewno*
10	*paliwo*
11	*proza*
12	*poezja*
13	*pokora*
14	*duma*
15	*fizyka*
16	*obawa*
17	*logika*
18	*papier*
19	*piasek*
20	*plastik*
21	*tłuszcz*
22	*beton*
23	*kwas*
24	*metal*
25	*miedź*
26	*olej*
27	*węgiel*
28	*biel*
29	*upał*
30	*złość*
31	*podziw*
32	*stałość*
33	*czerń*

#	COLLECTIVE SNG
1	*ławica*
2	*wataha*
3	*sekta*
4	*plemię*
5	*gromada*
6	*brygada*
7	*banda*
8	*stado*
9	*kadra*
10	*załoga*
11	*armia*
12	*ekipa*
13	*drużyna*
14	*rodzina*
15	*grupa*
16	*klan*
17	*pułk*
18	*zbiór*
19	*tłum*
20	*zespół*

#	PL TANTUM
1	*grabie*
2	*widły*
3	*nożyce*
4	*sanie*
5	*nosze*
6	*dżinsy*
7	*wrota*
8	*szachy*
9	*okulary*
10	*spodnie*
11	*drzwi*
12	*fusy*
13	*odmęty*
14	*pomyje*
15	*trzewia*
16	*wagary*
17	*manowce*
18	*wczasy*
19	*imieniny*
20	*ferie*
21	*urodziny*
22	*wakacje*

34	*szpak*	*sępy*
35	*żubr*	*pchły*
36	*wróbel*	*krety*
37	*ptak*	*koguty*
38	*wilk*	*kruki*
39	*orzeł*	*barany*
40	*pies*	*woły*

34	*smutek*
35	*starość*
36	*młodość*
37	*czystość*
38	*głód*
39	*wzrok*
40	*słuch*

Experiment 5

#	AFFIRMATIVE SENTENCES
1	*Adam widział małego królika/małe króliki*
2	*Magda poganiała swojego kolegę/swoich kolegów*
3	*Renata słyszała znanego muzyka/znanych muzyków*
4	*Artur karmił swojego chomika/swoje chomiki*
5	*Bożena polecała wybitnego pisarza/wybitnych pisarzy*
6	*Marek oczekiwał swojego sąsiada/swoich sąsiadów*
7	*Janek chwalił bystrego studenta/bystrych studentów*
8	*Justyna witała zagranicznego artystę/zagranicznych artystów*
9	*Policjant ścigał groźnego bandytę/groźnych bandytów*
10	*Piotrek odwiedzał swojego krewnego/swoich krewnych*
11	*Lucyna odganiała natrętnego komara/natrętne komary*
12	*Chłopiec gonił szarego szczura/szare szczury*
13	*Gospodarz strzygł białego barana/białe barany*
14	*Lekarz badał chorego pacjenta/chorych pacjentów*
15	*Kłusownik tropił rannego tygrysa/ranne tygrysy*
16	*Kelner wycierał srebrny widelec/srebrne widelce*
17	*Janek wybierał tani skuter/tanie skutery*
18	*Mechanik testował nowy silnik/nowe silniki*
19	*Krawiec szył modny sweter/modne swetry*
20	*Agata niosła ciężki plecak/ciężkie plecaki*
21	*Malarz czyścił swój pędzel/swoje pędzle*
22	*Antek czytał ciekawy magazyn/ciekawe magazyny*
23	*Uczeń strugał swój ołówek/swoje ołówki*
24	*Olga kupowała drogiego laptopa/drogie laptopy*
25	*Praczka prała brudny szalik/brudne szaliki*
26	*Maria odnawiała stary kredens/stare kredensy*
27	*Rolnik oglądał zepsuty traktor/zepsute traktory*
28	*Łukasz szorował tłusty garnek/tłuste garnki*
29	*Paulina myła swój talerz/swoje talerze*
30	*Kierowca tankował swój pojazd/swoje pojazdy*

#	NEGATIVE SENTENCES
1	*Adam nie widział małego królika/małych królików*
2	*Magda nie poganiała swojego kolegę/swoich kolegów*
3	*Renata nie słyszała znanego muzyka/znanych muzyków*
4	*Artur nie karmił swojego chomika/swoich chomików*
5	*Bożena nie polecała wybitnego pisarza/wybitnych pisarzy*
6	*Marek nie oczekiwał swojego sąsiada/swoich sąsiadów*
7	*Janek nie chwalił bystrego studenta/bystrych studentów*
8	*Justyna nie witała zagranicznego artystę/zagranicznych artystów*
9	*Policjant nie ścigał groźnego bandytę/groźnych bandytów*
10	*Piotrek nie odwiedzał swojego krewnego/swoich krewnych*
11	*Lucyna nie odganiała natrętnego komara/natrętnych komarów*
12	*Chłopiec nie gonił szarego szczura/szarych szczurów*
13	*Gospodarz nie strzygł białego barana/białych baranów*
14	*Lekarz nie badał chorego pacjenta/chorych pacjentów*
15	*Kłusownik nie tropił rannego tygrysa/rannych tygrysów*
16	*Kelner nie wycierał srebrnego widelca/srebrnych widelców*
17	*Janek nie wybierał taniego skutera/tanich skuterów*
18	*Mechanik nie testował nowego silnika/nowych silników*
19	*Krawiec nie szył modnego swetra/modnych swetrów*
20	*Agata nie niosła ciężkiego plecaka/ciężkich plecaków*
21	*Malarz nie czyścił swojego pędzla/swoich pędzli*
22	*Antek nie czytał ciekawego magazynu/ciekawych magazynów*
23	*Uczeń nie strugał swojego ołówka/swoich ołówków*
24	*Olga nie kupowała drogiego laptopa/drogich laptopów*
25	*Praczka nie prała brudnego szalika/brudnych szalików*
26	*Maria nie odnawiała starego kredensu/starych kredensów*
27	*Rolnik nie oglądał zepsutego traktora/zepsutych traktorów*
28	*Łukasz nie szorował tłustego garnka/tłustych garnków*
29	*Paulina nie myła swojego talerza/swoich talerzy*
30	*Kierowca nie tankował swojego pojazdu/swoich pojazdów*

Experiment 6

#	COLLECTIVE EXPRESSIONS
1	*Robotnicy wspólnie przenieśli pudło/pudła*
2	*Ogrodnicy wspólnie przesadzili drzewo/drzewa*
3	*Sportowcy wspólnie kopnęli piłkę/piłki*
4	*Studenci wspólnie podgrzali pizzę/pizze*
5	*Hydraulicy wspólnie odetkali rurę/rury*
6	*Mechanicy wspólnie naprawili urządzenie/urządzenia*
7	*Piraci wspólnie obejrzeli mapę/mapy*
8	*Malarze wspólnie przemalowali ścianę/ściany*
9	*Chłopi wspólnie przebudowali stodołę/stodoły*
10	*Dziewczynki wspólnie zaprosiły koleżankę/koleżanki*
11	*Nauczycielki wspólnie przesunęły ławkę/ławki*
12	*Astronauci wspólnie zbadali usterkę/usterki*
13	*Cukiernicy wspólnie ocenili ciastko/ciastka*
14	*Złodzieje wspólnie otworzyli kasę/kasy*
15	*Kucharze wspólnie wypełnili lodówkę/lodówki*
16	*Koleżanki wspólnie zorganizowały zebranie/zebrania*
17	*Turyści wspólnie zwiedzili galerię/galerie*
18	*Naukowcy wspólnie pokazali zdjęcie/zdjęcia*
19	*Studenci wspólnie przedstawili prezentację/prezentacje*
20	*Lekarze wspólnie zbadali chorego/chorych*
21	*Myśliwi wspólnie postrzelili sarnę/sarny*
22	*Prawnicy wspólnie przepisali umowę/umowy*
23	*Strażacy wspólnie przynieśli drabinę/drabiny*
24	*Fani wspólnie spotkali aktorkę/aktorki*
25	*Inżynierowie wspólnie zaprezentowali wynalazek/wynalazki*
26	*Piloci wspólnie przetestowali lotnisko/lotniska*
27	*Staruszki wspólnie nakarmiły kota/koty*
28	*Badacze wspólnie omówili artykuł/artykuły*
29	*Artyści wspólnie zaprezentowali dzieło/dzieła*
30	*Piosenkarze wspólnie zaśpiewali piosenkę/piosenki*

#	DISTRIBUTIVE EXPRESSIONS
1	*Każdy robotnik przeniósł pudło/pudła*
2	*Każdy ogrodnik przesadził drzewo/drzewa*
3	*Każdy sportowiec kopnął piłkę/piłki*
4	*Każdy student podgrzał pizzę/pizze*
5	*Każdy hydraulik odetkał rurę/rury*
6	*Każdy mechanik naprawił urządzenie/urządzenia*
7	*Każdy pirat obejrzał mapę/mapy*
8	*Każdy malarz przemalował ścianę/ściany*
9	*Każdy chłop przebudował stodołę/stodoły*
10	*Każda dziewczynka zaprosiła koleżankę/koleżanki*
11	*Każda nauczycielka przesunęła ławkę/ławki*
12	*Każdy astronauta zbadał usterkę/usterki*
13	*Każdy cukiernik ocenił ciastko/ciastka*
14	*Każdy złodziej otworzył kasę/kasy*
15	*Każdy kucharz wypełnił lodówkę/lodówki*
16	*Każda koleżanka zorganizowała zebranie/zebrania*
17	*Każdy turysta zwiedził galerię/galerie*
18	*Każdy naukowiec pokazał zdjęcie/zdjęcia*
19	*Każdy student przedstawił prezentację/prezentacje*
20	*Każdy lekarz zbadał* chorego/chorych
21	*Każdy myśliwy postrzelił sarnę/sarny*
22	*Każdy prawnik przepisał umowę/umowy*
23	*Każdy strażak przyniósł drabinę/drabiny*
24	*Każdy fan spotkał aktorkę/aktorki*
25	*Każdy inżynier zaprezentował wynalazek/wynalazki*
26	*Każdy pilot przetestował lotnisko/lotniska*
27	*Każda staruszka nakarmiła kota/koty*
28	*Każdy badacz omówił artykuł/artykuły*
29	*Każdy artysta zaprezentował dzieło/dzieła*
30	*Każdy piosenkarz zaśpiewał piosenkę/piosenki*

#	ITERATIVE EXPRESSIONS
1	*Robotnik kilkakrotnie przeniósł pudło/pudła*
2	*Ogrodnik kilkakrotnie przesadził drzewo/drzewa*
3	*Sportowiec kilkakrotnie kopnął piłkę/piłki*
4	*Student kilkakrotnie podgrzał pizzę/pizze*
5	*Hydraulik kilkakrotnie odetkał rurę/rury*
6	*Mechanik kilkakrotnie naprawił urządzenie/urządzenia*
7	*Pirat kilkakrotnie obejrzał mapę/mapy*
8	*Malarz kilkakrotnie przemalował ścianę/ściany*
9	*Chłop kilkakrotnie przebudował stodołę/stodoły*
10	*Dziewczynka kilkakrotnie zaprosiła koleżankę/koleżanki*
11	*Nauczycielka kilkakrotnie przesunęła ławkę/ławki*
12	*Astronauta kilkakrotnie zbadał usterkę/usterki*
13	*Cukiernik kilkakrotnie ocenił ciastko/ciastka*
14	*Złodziej kilkakrotnie otworzył kasę/kasy*
15	*Kucharz kilkakrotnie wypełnił lodówkę/lodówki*
16	*Koleżanka kilkakrotnie zorganizowała zebranie/zebrania*
17	*Turysta kilkakrotnie zwiedził galerię/galerie*
18	*Naukowiec kilkakrotnie pokazał zdjęcie/zdjęcia*
19	*Student kilkakrotnie przedstawił prezentację/prezentacje*
20	*Lekarz kilkakrotnie zbadał chorego/chorych*
21	*Myśliwy kilkakrotnie postrzelił sarnę/sarny*
22	*Prawnik kilkakrotnie przepisał umowę/umowy*
23	*Strażak kilkakrotnie przyniósł drabinę/drabiny*
24	*Fan kilkakrotnie spotkał aktorkę/aktorki*
25	*Inżynier kilkakrotnie zaprezentował wynalazek/wynalazki*
26	*Pilot kilkakrotnie przetestował lotnisko/lotniska*
27	*Staruszka kilkakrotnie nakarmiła kota/koty*
28	*Badacz kilkakrotnie omówił artykuł/artykuły*
29	*Artysta kilkakrotnie zaprezentował dzieło/dzieła*
30	*Piosenkarz kilkakrotnie zaśpiewał piosenkę/piosenki*

APPENDIX 2

Results of a pretest for Experiment 2. Mean values and standard deviations of responses from 10 native Polish speakers rating how often each word is used to refer to more than one entity on a scale from 1 (very rarely) to 5 (very often).

#	COLLECTIVE SNG	M	SD
1	*trzoda*	4.7	0.5
2	*banda*	4.5	0.7
3	*chmara*	4.5	0.7
4	*ławica*	4.5	0.7
5	*rodzina*	4.5	0.7
6	*zgraja*	4.5	0.8
7	*drużyna*	4.4	0.7
8	*ekipa*	4.4	0.8
9	*grupa*	4.4	0.8
10	*kadra*	4.4	0.8
11	*klan*	4.4	0.7
12	*komisja*	4.4	0.8
13	*obsada*	4.4	1.0
14	*załoga*	4.4	0.8
15	*stado*	4.3	0.8
16	*tłum*	4.3	0.8
17	*wataha*	4.3	0.8
18	*armia*	4.2	0.8
19	*czereda*	4.2	0.8
20	*eskadra*	4.2	1.0
21	*legion*	4.2	1.3
22	*naród*	4.2	1.3
23	*ród*	4.2	1.0
24	*rój*	4.2	0.9
25	*zbiór*	4.2	0.8
26	*bractwo*	4.1	0.7

#	UNITARY SNG	M	SD
1	*bandyta*	1.5	1.3
2	*klient*	1.3	0.5
3	*kaczka*	1.2	0.4
4	*owad*	1.2	0.4
5	*pies*	1.2	0.4
6	*rolnik*	1.2	0.4
7	*artysta*	1.1	0.3
8	*baran*	1.1	0.3
9	*bocian*	1.1	0.3
10	*borsuk*	1.1	0.3
11	*byk*	1.1	0.3
12	*chłopiec*	1.1	0.3
13	*czapla*	1.1	0.3
14	*drozd*	1.1	0.3
15	*dzik*	1.1	0.3
16	*gawron*	1.1	0.3
17	*gazela*	1.1	0.3
18	*gołąb*	1.1	0.3
19	*górnik*	1.1	0.3
20	*hiena*	1.1	0.3
21	*jeleń*	1.1	0.3
22	*kogut*	1.1	0.3
23	*kolega*	1.1	0.3
24	*komar*	1.1	0.3
25	*koń*	1.1	0.3
26	*kos*	1.1	0.3

27	*brygada*	4.1	0.9
28	*gromada*	4.1	1.1
29	*hołota*	4.1	1.1
30	*kompania*	4.1	0.9
31	*plemię*	4.1	1.3
32	*partia*	4.0	1.1
33	*policja*	4.0	0.8
34	*zastęp*	4.0	1.5
35	*ferajna*	3.9	1.3
36	*lud*	3.9	1.4
37	*motłoch*	3.9	1.7
38	*sekta*	3.9	1.4
39	*zespół*	3.9	1.4
40	*gremium*	3.8	1.5
41	*grono*	3.8	1.5
42	*kapela*	3.8	1.4
43	*komitet*	3.8	1.4
44	*zarząd*	3.8	1.4
45	*pułk*	3.7	1.2
46	*nacja*	3.6	1.5
47	*sztab*	3.6	0.8
48	*sejm*	3.5	1.2
49	*oddział*	3.4	1.3
50	*klasa*	3.3	1.2
51	*obóz*	3.1	1.1
52	*osiedle*	3.1	1.5
53	*klub*	3.0	1.6
54	*kongres*	3.0	1.5
55	*osada*	2.7	1.5
56	*senat*	2.7	1.3
57	*spółka*	2.4	1.4
58	*miasto*	2.2	1.5
59	*wydział*	2.2	1.2
60	*firma*	2.1	1.4
61	*wieś*	1.9	1.0
62	*kraj*	1.6	1.1

27	*kot*	1.1	0.3
28	*koza*	1.1	0.3
29	*kret*	1.1	0.3
30	*królik*	1.1	0.3
31	*krowa*	1.1	0.3
32	*kruk*	1.1	0.3
33	*kupiec*	1.1	0.3
34	*lekarz*	1.1	0.3
35	*lis*	1.1	0.3
36	*malarz*	1.1	0.3
37	*mucha*	1.1	0.3
38	*orzeł*	1.1	0.3
39	*sójka*	1.1	0.3
40	*świnia*	1.1	0.3
41	*szpak*	1.1	0.3
42	*wilk*	1.1	0.3

#	PL TANTUM	M	SD
1	*grabie*	3.3	0.8
2	*nożyce*	3.2	0.9
3	*dżinsy*	3.1	0.9
4	*drzwi*	2.8	0.8
5	*okulary*	2.8	1.1
6	*sanie*	2.8	0.9
7	*szachy*	2.8	1.1
8	*widły*	2.8	0.9
9	*spodnie*	2.7	1.2
10	*nosze*	2.6	1.1
11	*wrota*	2.6	1.3

#	MASS	M	SD
1	*szlachta*	3.9	1.3
2	*piasek*	3.7	1.4
3	*żwir*	3.5	1.4
4	*drewno*	3.3	1.3
5	*żyto*	3.3	1.7
6	*ryż*	3.3	1.7
7	*igliwie*	3.3	1.3
8	*groch*	3.2	1.0
9	*bilon*	3.0	1.6
10	*fasola*	2.9	0.9
11	*cukier*	2.9	1.7
12	*mąka*	2.7	1.8
13	*sól*	2.7	1.6
14	*kasza*	2.6	1.9
15	*węgiel*	2.5	1.5
16	*papier*	2.4	1.3
17	*złoto*	2.4	1.3
18	*mięso*	2.2	1.1
19	*szkło*	2.2	1.3
20	*tłuszcz*	2.2	1.2
21	*plastik*	2.1	1.3
22	*metal*	2.0	1.2
23	*wapno*	2.0	1.2
24	*błoto*	1.8	1.3
25	*kwas*	1.8	1.1
26	*paliwo*	1.8	1.3
27	*beton*	1.7	1.1
28	*miedź*	1.7	1.1
29	*tworzywo*	1.6	1.1
30	*olej*	1.5	0.7
31	*wata*	1.5	0.7

#	PL	M	SD
1	*aligatory*	4.9	0.3
2	*antylopy*	4.9	0.3
3	*kuny*	4.9	0.3
4	*łasice*	4.9	0.3
5	*lisy*	4.9	0.3
6	*lwice*	4.9	0.3
7	*lwy*	4.9	0.3
8	*muzycy*	4.9	0.3
9	*nosorożce*	4.9	0.3
10	*owce*	4.9	0.3
11	*pacjenci*	4.9	0.3
12	*ptaki*	4.9	0.3
13	*pumy*	4.9	0.3
14	*ryby*	4.9	0.3
15	*sarny*	4.9	0.3
16	*sępy*	4.9	0.3
17	*sikorki*	4.9	0.3
18	*studenci*	4.9	0.3
19	*szczury*	4.9	0.3
20	*węże*	4.9	0.3
21	*woły*	4.9	0.3
22	*wróble*	4.9	0.3
23	*wrony*	4.9	0.3
24	*zające*	4.9	0.3
25	*żółwie*	4.9	0.3
26	*żubry*	4.9	0.3
27	*żuki*	4.9	0.3
28	*żyrafy*	4.9	0.3
29	*krokodyle*	4.8	0.4
30	*motyle*	4.8	0.4
31	*mrówki*	4.8	0.4
32	*pantery*	4.8	0.4
33	*pchły*	4.8	0.4

34	*pisarze*	4.8	0.4
35	*sąsiedzi*	4.8	0.4
36	*tygrysy*	4.8	0.4
37	*wiewiórki*	4.8	0.4
38	*zebry*	4.8	0.4
39	*żurawie*	4.8	0.4
40	*drzewa*	4.8	0.4
41	*myszy*	4.7	0.7
42	*krewni*	4.6	0.8

SUMMARY

This thesis presents the results of six psycholinguistic experiments designed to learn more about the extraction of numerical information from singular and plural nouns and the integration of this information with lexical semantics and sentential context.

Three areas were investigated. The first area focused on the mechanisms of online conflict resolution between the lexical and grammatical number for collective nouns, mass nouns and *pluralia tantum*. The specific research problem was whether the initial numerical representation of noun referents is driven primarily by the grammatical designation or the lexical semantics. The second area focused on the effects of morphological marking on the processing of grammatical number. The specific research problem was the possible facilitatory role of an overt number ending in comparison to a zero morpheme. The third area focused on the interpretation of grammatical number in sentential context. The specific research problem was the influence of sentential negation and distributive quantifiers. Research problems within each area were addressed using experimental techniques based on three number-interference phenomena: the numerical Stroop effect, the SNARC effect and the size congruity effect (SCE). The experiments were conducted using Polish stimuli with native Polish speakers as participants.

The data obtained in the experiments suggest that by default comprehenders expect grammatical number to be a reliable cue for the numerosity of the objects under discussion. The grammatical number value of a word seems to be identified automatically, even if it is irrelevant for the task. Conceptual singularity or plurality is consistently activated for grammatically singular or plural words, respectively, even if the lexical meaning is at odds with the morphosyntactic marking. There is also no evidence in the data that the initial number representation is affected by sentential negation, even though negation influences the numerical interpretation of the entire expression. Additionally, the results suggest that, compared to a zero ending, an overt number suffix facilitates the extraction of a numerical concept.

An additional goal of the present work was to better understand the relations between language and general numerical cognition. The data revealed that the processing of grammatical number resembles the processing of other quantity-related concepts in at least two ways: (i) it interferes with the assessment of the visual numerosity of stimuli during a counting task; (ii) it makes use of the space-number connection, linking singular nouns with the left response side and plural nouns with the right response side. On the other hand, there was no evidence in the data that grammatical number can interfere with the discrimination of visual size, unlike other types of symbolic quantities, like numerals or digits.

Basing the techniques on the three interference phenomena was also intended to develop further the methodology of experimental language research. The experiments added more evidence that the Stroop effect and the SNARC effect are suitable tools for studying the processing of grammatical number in language. In contrast, the failure to elicit a number-size interference may suggest that SCE is not useful in studying grammatical number.

STRESZCZENIE

Praca przedstawia wyniki sześciu eksperymentów psycholingwistycznych przeprowadzonych w celu zbadania mechanizmów identyfikowania informacji liczbowej związanej z rzeczownikami pojedynczymi i mnogimi oraz procesu łączenia tej informacji z semantyką leksykalną wyrazów i z kontekstem zdaniowym.

Eksperymenty koncentrowały się na trzech obszarach badawczych. Obszar pierwszy obejmował mechanizmy rozwiązywania konfliktu między liczbą gramatyczną i leksykalną dla rzeczowników kolektywnych, niepoliczalnych oraz *pluralia tantum*. Główny problem badawczy dotyczył tego, czy podstawowa liczbowa interpretacja takich rzeczowników opiera się na informacji gramatycznej czy raczej na semantyce leksykalnej. Kolejny obszar badawczy obejmował rolę morfologicznego wykładnika liczby. Testowana hipoteza dotyczyła możliwości wpływania rodzaju wykładnika na proces identyfikacji wartości liczby gramatycznej. Ostatni obszar obejmował przetwarzanie liczby gramatycznej w kontekstach zdaniowych. Główny problem badawczy dotyczył wpływu negacji zdaniowej oraz kwantyfikatorów dystrybutywnych. Do poszukiwania odpowiedzi na konkretne problemy badawcze w tych obszarach wykorzystano techniki eksperymentalne oparte o trzy zjawiska związane z liczbową interferencją: liczbowy efekt Stroopa, efekt SNARC oraz efekt spójności rozmiaru. W eksperymentach uczestniczyli natywni użytkownicy języka polskiego a materiały eksperymentalne były w języku polskim.

Dane pozyskane z eksperymentów sugerują, że użytkownicy języka traktują domyślnie liczbę gramatyczną jako wiarygodne źródło informacji o liczebności opisywanych obiektów. Wartość liczby gramatycznej jest automatycznie identyfikowana, nawet jeśli nie jest to konieczne dla wykonania danego zadania. Koncept pojedynczości jest systematycznie aktywowany dla rzeczowników pojedynczych a koncept mnogości – dla mnogich, również gdy znaczenie leksykalne wyrazu nie jest zgodne z jego morfoskładniowym oznaczeniem. Rezultaty wskazują również, że obecność w zdaniu negacji nie zmienia podstawowej interpretacji samego rzeczownika, chociaż negacja wpływa na interpretację liczbową całego wyrażenia. Ponadto wyniki eksperymentów przemawiają za prawdziwością hipotezy, że

obecność sufiksu liczbowego przyspiesza dostęp do informacji liczbowej w porównaniu do morfemu zerowego.

Dodatkowym celem pracy było lepsze zrozumienie relacji między językiem i poznaniem liczbowym. Eksperymenty pokazały, że przetwarzanie liczby gramatycznej przypomina przetwarzanie innych konceptów związanych z liczebnością pod co najmniej dwoma względami: (i) interferencji z określaniem liczebności wizualnie przedstawionych obiektów; (ii) powiązania wielkości liczbowej z relacjami przestrzennymi (rzeczowniki pojedyncze silniej związane z lewą stroną a rzeczowniki mnogie – z prawą). Nie znaleziono jednak dowodów na relację między liczbą gramatyczną i rozmiarem, choć relacja taka istnieje dla liczebników oraz cyfr.

Wybór zjawisk związanych z liczbową interferencją jako podstawy technik badawczych miało na celu również wniesienie wkładu w rozwój metodologii eksperymentalnych badań nad językiem. Eksperymenty dostarczyły kolejnych dowodów na przydatność efektu Stroopa i efektu SNARC jako narzędzi badania przetwarzania liczby gramatycznej w języku. Z kolei brak dowodów na interakcję liczby gramatycznej z rozmiarem wskazuje, że przydatność efektu spójności rozmiaru w tej funkcji może być ograniczona.

Wrocław, 14.02.2020

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Piotr Gulgowski