Where the Mass Counts: Common Cortical Activation for Different Kinds of Nonsingularity

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Abstract

■ Typically, plural nouns are morphosyntactically marked for the number feature, whereas mass nouns are morphosyntactically singular. However, both plural count nouns and mass nouns can be semantically interpreted as nonsingular. In this study, we investigated the hypothesis that their commonality in semantic interpretation may lead to common cortical activation for these different kinds of nonsingularity. To this end, we examined brain activation patterns related to three types of nouns while participants were listening to a narrative. Processing of plural compared with singular nouns was related to increased activation in the left angular gyrus. Processing of mass nouns compared with singular count nouns was related to increased activity bilaterally in the superior temporal cortex and also in the left angular gyrus. No significant activation was observed in the direct comparison between plural and mass nouns. We conclude that the left angular gyrus, also known to be relevant for numerical cognition, is involved in the semantic interpretation of different kinds of nonsingularity. ■

INTRODUCTION

When listening to connected speech, we are constantly engaged in the on-line interpretation of what has been said. Fundamentally, we map linguistic information from different levels (phonology, morphology, syntax) to meaning. One basic aspect of meaning relates to quantity, which can be expressed by different linguistic means. In this study we address the question whether different linguistic means to express nonsingularity lead to common cortical activation.

Kinds of Nonsingularity

One obvious way to express nonsingularity is the use of morphological markers. In English, German, and many other languages, the use of number markers is obligatory in appropriate context for a certain class of nouns, which are commonly called "count nouns" (see below). Most often, the number value expressed by this marker is plural,[1] which refers to more than one individual, and is thus opposed to singular, which typically refers to exactly one individual entity.

However, singular forms may also express a generic meaning. Generic terms can give reference to a kind of entity (e.g., "***The potato*** *was first cultivated in South America.*"; Carlson & Pelletier, 1995, p. 2). In this usage of singular nouns, singular does not individuate one distinct real world referent but refers to the kind of referents. It is this expansion of meaning in singular forms that led to the assumption that the singular value does not necessarily express any number but is rather underspecified with respect to quantity. In contrast, the value of plural is seen to be unambiguously connected with a quantity interpretation of "more than one" and is usually expressed by an overt marker (Corbett, 2000). Thus, singular has been regarded as the unmarked[2] instance of morphological number paradigms (Greenberg, 1966).

Morphological plural markers do have a specific form to express their meaning. In the English noun system, except for very few words, the suffix -s is regularly used to mark plural, whereas the singular is left unmarked. Although the German plural system is much more complicated, again most of the plural nouns are overtly marked using a suffix and/or a stem vowel fronting called "umlaut" (Wiese, 2009; Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995). Even in nouns that do not show any overt morphological marking (e.g., *Löffel* [spoon], *Becher* [bowl], or *Wagen* [car]), plurality can be inferred from context, in particular from the kind of article or quantifier used (e.g., ***der*** *Löffel*$_{sg.}$ vs. ***die*** *Löffel*$_{pl.}$) or from subject–verb agreement.

As mentioned above, the singular–plural distinction is typically applied to a set of words such as apple, table, or book referred to as count nouns. Count nouns are thought to be characterized by their property to individuate their reference. Quine (1960) illustrated this as follows: "Inherent in the meaning of a count noun, like 'apple,' is what counts as one apple and what as another…such terms possess built-in modes of dividing their reference." Nouns

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not dividing their reference such as water, rice, furniture, or poetry are traditionally called mass nouns. Mass nouns are said to have homogeneous reference, meaning that they can be used to refer to each of several objects as well as to the whole formed by these objects and also to parts of these objects (Bunt, 2006). As Quine (1960) put it, "Any sum of parts that are water is water." On the basis of the fact that mass nouns, but not count nouns, appear to exist in all natural languages, it has been argued that mass nouns are the default value, whereas count nouns represent the marked case (Chierchia, 1998; Krifka, 1995).

The difference in linguistic reference is obviously related to specific perceptual properties of mass and count nouns. Mass nouns have boundaries, which are perceptually less accessible than those of count nouns. Recent evidence suggests that construing an entity as an object (rather than as stuff) seems to be favored by regularity of structure, repeatability of structure, and existence of structure-dependent functions (Prasada, Ferenz, & Haskell, 2002). In fact, characteristic properties of mass and count nouns cause differences in perceptual processing (e.g., vanMarle & Scholl, 2003). These perceptual differences already influence cognitive representations of infants, such that rigid cohesive objects (represented by count nouns) occupy a privileged status in mental object representation (Huntley-Fenner, Carey, & Solimando, 2002; Chiang & Wynn, 2000).

Beyond the already sketched differences between mass and count nouns with regard to some aspects of their item-specific word meaning, mass nouns have also specific morphosyntactic properties. They are either morphosyntactically singular (most cases as fruit or garbage) or plural (rare cases as measles or spaghetti) but do not have both forms. Moreover, mass and count nouns differ in their possible combinations with numerals, determiners, and adjectives (Bunt, 2006; Gillon, 1992).

The classical mass–count dichotomy has been challenged by claims that the actual distinction to be made is between noncount nouns and count nouns (e.g., Laycock, 2006). According to this view, noncount nouns are also nonsingular, whereas count nouns may be singular as well as nonsingular. Thus, both noncount nouns (irrespective of their morphological marking) and plural count nouns represent different forms of nonsingularity. One central argument for this distinction is that both noncount and plural count nouns do not accept singular quantifiers. Although it is perfectly fine to speak of all water/all tables, some water/some tables, or more water/more tables (i.e., to use nonsingular quantifiers), it is not acceptable to say *a water/*a tables, *each water/*each tables, or *one water/*one tables. Other authors, too, have put forward arguments in favor of a nonsingularity or plurality account of mass nouns (e.g., Chierchia, 1998).

The distinction between (noncount) mass and count nouns, however intuitively clear as it seems, is actually difficult to make precise. This imprecision occurs along two dimensions: (i) morphosyntactic patterning and (ii) item-specific word meaning. First, morphosyntactic patterning may be language-specific. For example, although some nouns (e.g., spinach, hair, pasta, toast) may appear in mass morphosyntax in English, their French equivalents (*épinard*, *cheveux*, *pates*, *rotis*) may show the morphosyntactic patterning of count nouns (Inagaki & Barner, 2009). Moreover, some nouns (e.g., string, stone) can be regarded as mass–count flexible, meaning that their morphosyntactic patterning may systematically shift depending on which aspects of their entity (individual or stuff) are referred to (Barner & Snedeker, 2005). In fact, under certain conditions virtually every count noun can be used as mass noun and vice versa (Bunt, 2006; Jackendoff, 1991). For instance, it is possible to say, "There was dog all over the street," in which case the bare singular and the distributive location force a substance interpretation of dog (Jackendoff, 1991). Second, a subset of mass nouns like furniture and jewelry, called collective mass nouns (Bunt, 1985), atomic mass nouns (Gillon, Kehayia, & Taler, 1999), or object mass nouns (Barner & Snedeker, 2005), can be distinguished from standard substance mass nouns like mustard or water. Whereas such collective mass nouns show the typical morphosyntactic patterning so far described for mass nouns, they clearly denote individuals. Thus, in these cases, morphosyntax and lexical meaning dissociate.

In summary, although singular count nouns express singularity, there are different ways to express nonsingularity—either with plural count nouns or with noncount nouns (i.e., mass nouns). The subset of substance mass nouns (i.e., excluding collective mass nouns) that are not mass–count flexible and not marked for plural is most clearly distinguishable from count nouns. In the remainder of this article, we will use the terms "singular" (noun) for singular count nouns, "plural" (noun) for plural count nouns, and the classical term "mass noun" in Laycock's sense of noncount nouns. Plural nouns have been argued to be more marked than singular nouns (Greenberg, 1966), whereas count nouns (singular as well as plural) have been argued to be more marked than mass nouns (Chierchia, 1998; Krifka, 1995).

Psycholinguistic and Neurolinguistic Evidence

Singular and Plural Nouns

The processing of plural nouns can be assumed to be more demanding than the processing of singular nouns for two reasons: First, if singular nouns are regarded as unmarked and plural nouns are regarded as marked, processing the additional plural feature may take some time. Second, plural nouns are often—although not always—morphologically more complex than singular nouns. In these cases, the decomposition into affix and stem may cost some extra time as well. However, this may be true only for regular inflection, assumed to be processed via a decomposition procedure (Marcus et al., 1995), whereas irregular plural forms—assumed to be recognized via direct retrieval from the mental lexicon—may not lead to higher processing load compared with singular nouns. Consistent with these assumptions, regularly inflected plural nouns elicited longer RTs than singular nouns in a lexical decision task, although this plural disadvantage was not observed for irregular inflection (Mondini, Kehayia, Gillon, Arcara, & Jarema, 2009; see also Gillon et al., 1999).

During cognitive development, the acquisition of singular–plural morphosyntax helps in the conceptual distinction between sets of one and more than one objects (Barner, Thalwitz, Wood, Yang, & Carey, 2007). Moreover, cross-linguistic studies showed that children acquiring a language with consistent grammatical number marking like Russian or English knew the exact meaning of small numbers (one, two, and three) earlier than children acquiring a language without overt number marking like Japanese (Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007).

Evidence that the quantity information of morphological plural markers is automatically processed comes from a Stroop-like task in which participants had to judge the numerosity (one or two) of visually presented words while ignoring their contents. Although irrelevant for the task, participants showed interference from the plural marker, if the number of words presented was incongruent with it, leading to increased RTs if only one noun was presented, which was marked for plural compared with one singular noun (Berent, Pinker, Tzelgov, Bibi, & Goldfarb, 2005). Interestingly, there was no interference of two nouns presented in singular, which has been interpreted as evidence for the fact that singular nouns—in contrast to plural nouns—are unmarked for the number feature.

To the best of our knowledge, there is only one publication so far addressing the neuronal correlates of grammatical number processing. Carreiras, Carr, Barber, and Hernandez (2010) reported activation in the right intraparietal sulcus when participants were asked to read pairs of words with number agreement violations (e.g., *los piano* [the$_{\text{m-p}}$ piano$_{\text{m-s}}$]) as opposed to phrases with gender agreement violations (e.g., *la piano* [the$_{\text{f-s}}$ piano$_{\text{m-s}}$]) or with no violation (e.g., *el piano* [the$_{\text{m-s}}$ piano$_{\text{m-s}}$]). Given that this activation was number specific (i.e., not present for gender violations), it was concluded that it reflected quantity processing. In fact, numerous studies on the neuronal bases of numerical cognition have shown that the intraparietal sulcus of both hemispheres is crucially involved in quantity processing (for a review, see Dehaene, Piazza, Pinel, & Cohen, 2003). According to this view, as specified in the triple code model put forward by Dehaene and colleagues (Dehaene et al., 2003; Dehaene & Cohen, 1995), the abstract quantity representation is related to the activity of the intraparietal sulcus, whereas knowledge of arithmetic (and other) facts is associated with the left angular gyrus (see also Delazer et al., 2003, 2005).

However, there is also evidence that the left angular gyrus may be more directly involved in quantity processing. TMS applied to the left angular gyrus has repeatedly been shown to disrupt quantity processing (Cattaneo, Silvanto, Pascual-Leone, & Battelli, 2009; Rusconi, Walsh, & Butterworth, 2005; Göbel, Walsh, & Rushworth, 2001; see also Sandrini, Rossini, & Miniussi, 2004, for stimulation of the left supramarginal gyrus). How may the left angular gyrus be related to number representation? Since Gerstmann (1930), it has been argued that this area is involved in finger representation and, secondary to this, to left–right orientation, writing, and numerical abilities. With respect to the latter, there is increasing evidence for the importance of finger representations in numerical cognition (e.g., Domahs, Moeller, Huber, Willmes, & Nuerk, 2010; Domahs, Krinzinger, & Willmes, 2008; Andres, Seron, & Olivier, 2007; Sato, Cattaneo, Rizzolatti, & Gallese, 2007). Thus, as Rusconi et al. (2005) put it: “Following a process of abstraction from the finger series, the mental number line (or better, the mental *digit* line) might represent the substitute of early finger counting and be supported by an area which also supports finger gnosis.” This area could be the left angular gyrus. Alternative views suggest that it is the mapping between symbolic input representations and quantity representation proper (Ansari, 2008) or visuospatial processing (Cattaneo et al., 2009; Hubbard, Piazza, Pinel, & Dehaene, 2005) that is subserved by the left angular gyrus.

Mass and Count Nouns

Singular mass nouns may differ from singular count nouns at different levels of cognitive processing (e.g., lexical, semantic, or syntactic), as discussed above. A number of studies failed to demonstrate behavioral differences between these noun types in lexical decision tasks (Mondini et al., 2008; El Yagoubi et al., 2006; Bisiacchi, Mondini, Angrilli, Marinelli, & Semenza, 2005), whereas others reported longer RTs for mass nouns compared with singular nouns (Mondini et al., 2009; Gillon et al., 1999). Moreover, electrophysiological correlates of early automatic lexical classification of written words (i.e., the so-called N150 component) revealed significant differences between these types of words such that in the left anterior hemisphere, mass nouns elicited a stronger negativity than singular nouns while the opposite pattern was observed in the left posterior quadrant (Mondini et al., 2008; El Yagoubi et al., 2006). Generally, processing of singular nouns elicited networks more confined to the left hemisphere, whereas mass nouns activated a network more widely distributed both within the left hemisphere and across hemispheres (Mondini et al., 2008; El Yagoubi et al., 2006).

Although the mass–count classification can be performed implicitly in lexical decision, Bisiacchi and colleagues used a semantic categorization task to directly address the semantic processing level (Bisiacchi et al., 2005). After a short instruction phase, participants had to judge given words explicitly as mass or count noun. Mass nouns yielded significantly delayed responses compared with (singular) count nouns and again more diffuse electrophysiological activity across both hemispheres. Interestingly, in this paradigm singular nouns elicited a stronger early negative component (N150) than count nouns in left anterior brain regions, that is, the opposite as has been reported for lexical decision tasks (Mondini et al., 2008; El Yagoubi et al., 2006).

As far as the syntactic processing level is concerned, the picture is far from being clear yet. On the one hand, El Yagoubi et al. (2006) reported longer RTs for mass than for singular nouns when participants had to confirm grammaticality of given sentences. On the other hand, no processing disadvantage in lexical decision was observed for mass nouns compared with singular nouns if a priming sentence fragment was initially presented (Mondini et al., 2009). Mondini and colleagues concluded that the disadvantage for mass compared with singular nouns does not affect the on-line processing of normal fluent spoken language (as is the case for the disadvantage of plural compared with singular nouns).

Steinhauer, Pancheva, Newman, Gennari, and Ullman (2001) reported an anterior negativity between 300 and 600 msec for the processing of count nouns compared with mass nouns in sentence context. As this effect resembled that of anterior negative components linked to grammatical processing and not to a posterior N400 component related to lexical–semantic processing, Steinhauer and colleagues concluded that the distinction between mass and count nouns was primarily of syntactic nature. Unfortunately, Steinhauer et al. (2001) did not indicate whether their mass and/or count nouns were marked for plural or not (which is also true for all other EEG studies reported so far). One may assume that both mass and count nouns were not marked for plural, as suggested by the examples given in the original article. Yet, the conclusion that (singular) count nouns may be more demanding in syntactic processing compared with (singular) mass nouns is weakened by the fact that the effect observed cannot safely be interpreted as increased negativity for count nouns, excluding the alternative of a relative positive waveform for mass nouns. Thus, as Steinhauer et al. (2001) admitted, it could be either count nouns or mass nouns that required additional processing resources, depending on the baseline chosen.

As discussed in the section above, there is a subset of mass nouns, called collective mass nouns (e.g., furniture, jewelry), which behave morphosyntactically as mass nouns, while their individual meaning shares the aspect of individuation with count nouns. This fact has been shown to have consequences in cognitive processing. It is well known that collective mass nouns elicit errors in subject–verb congruence, such that the verb is marked for plural although the collective mass noun subject is morphologically singular (Hokkanen, 1999). Moreover, English-speaking children and adults have been shown to base their quantity judgments on numerosity for both count nouns like shoes and collective mass nouns like furniture, but rather on volume for nonindividuating substance words like mustard (Barner & Snedeker, 2005). A similar pattern of performance was also observed for participants speaking Japanese, a classifier language without any morphosyntactic mass–count distinction (Inagaki & Barner, 2009). Both studies highlight the importance of word-specific lexical information or perceptual properties of referents for their quantity interpretation and demonstrate that the existence of mass–count morphosyntax is not necessary to specify individuation. This point was supported by studies that showed that children respect an object–substance distinction in word learning before their acquisition of mass–count syntax (McPherson, 1991; Soja, Carey, & Spelke, 1991).

In summary, there is behavioral and EEG evidence suggesting that mass nouns may require more cognitive processing resources than count nouns, as—depending on the specific experimental paradigm chosen—they may be associated with longer RTs and more widespread brain activity (Mondini et al., 2008, 2009; El Yagoubi et al., 2006; Gillon et al., 1999). This processing perspective seems to contradict the assumption, based on linguistic typology, that mass nouns are the default and count nouns are marked (Chierchia, 1998; Krifka, 1995). With respect to the specific neurocognitive underpinnings of mass noun processing, results are still rather vague and contradictory, which is not all that surprising given the coarse spatial resolution used, the different variables (not) controlled for, and the variety of experimental designs chosen.

The Present Study

In this study, we investigate the on-line processing of singular nouns, plural nouns, and mass nouns during unconstrained, natural narrative comprehension. So far, there is only one neuroimaging study investigating the processing of grammatical number (Carreiras et al., 2010). However, whereas in the paradigm used by Carreiras et al. (2010) participants read word pairs containing grammatical violations, in this study target words are embedded in a context of fluent, grammatical speech presented auditorily, thus avoiding any metalinguistic task demands. Until now, results on the localization of mass and count noun processing rely on EEG experiments and seem partly inconsistent. Crucially, so far, no study has directly compared the processing of plural nouns and mass nouns using neuroimaging methods.

In general, it can be expected that networks activated for all three types of nouns are largely overlapping, mainly located in peri-sylvian regions of the dominant hemisphere. Thus, even extensive patient studies did not yield clear double dissociations between mass and count nouns (e.g., Semenza, Mondini, & Marinelli, 2000; Semenza, Mondini, & Cappelletti, 1997). With respect to the singular–plural distinction, based on behavioral studies one may expect increased activation for plural compared with singular nouns, reflecting additional processing costs for the plural feature. Concerning the mass–count distinction, the expectations are somewhat more controversial. According to linguistic typology mass nouns are the unmarked case, whereas behavioral and EEG studies suggest that, from a processing point of view, more activation could be expected for mass nouns than for singular nouns. Finally, a direct comparison between mass nouns and plural nouns should reveal whether there are common areas activated for both types of words. Quantity judgments for plural nouns are assumed to be based on numerosity whereas those for mass nouns (at least those referring to substances) are assumed to be based on volume (Inagaki & Barner, 2009; Barner & Snedeker, 2005). Irrespective of this difference, both mass nouns and plural nouns can be regarded as nonsingular (Laycock, 2006; Chierchia, 1998). Common activation in some area dedicated to quantity or magnitude processing may reflect common nonsingularity. Candidate areas for such common activation may be the intraparietal sulcus bilaterally or the left angular gyrus.

METHODS

The same data set has been analyzed previously focusing on another research question, using a different methodology (Whitney et al., 2009).

Participants

Nineteen men participated in the fMRI study. Because of head movement, data of three participants had to be discarded from further analysis. The remaining 16 participants were native speakers of German with a mean age of 27.0 years (*SD* = 6.6) and a mean level of education of 14.5 years (*SD* = 1.7). All subjects were right-handed according to the Edinburgh Inventory of Handedness (Oldfield, 1971) and showed average or above average verbal IQ as assessed by the German MWT-B multiple choice vocabulary test (Lehrl, Triebig, & Fischer, 1995; mean estimated verbal IQ = 120.1, *SD* = 17.2). Subjects were screened for general MRI compatibility and gave informed consent. They received €20 for participation in the study. The study was approved by the local ethics committee.

Task and Procedure

Participants were placed in the scanner and equipped with MRI compatible headphones. They were instructed to close their eyes and listen carefully to a story. No information was given about the purpose of the study. To ensure that participants attended to the content, they were informed at the beginning of the experiment that a short interview would take place after the MRI session about the content of the story. Each of the 10 questions, asked in chronological order, required the recall of a critical event and referred to a specific episode/macroproposition. Participants succeeded whenever the essence of the respective event was captured, that is, no overly detailed recall was required. Answers were classified as "correct" or "incorrect," accordingly. No time restrictions were given.

In contrast to previous studies, we used no metalinguistic task, such as grammaticality judgment, lexical decision, or semantic categorization. Rather, we chose a more naturalistic approach to investigate linguistic processing, which did not require any overt decision or motor response. Thus, on the one hand, we avoided additional cognitive, academic, or attentional constraints that may be related to metalinguistic tasks to increase ecological validity of our paradigm (Small & Nusbaum, 2004). On the other hand, the task chosen implicates some lack of control about potentially relevant (psycho-) linguistic variables. We addressed this issue performing additional post hoc analyses examining these variables (see Stimuli, Results, and Discussion sections).

Stimuli

A slightly modified version of the German novella "*Der Kuli Kimgun*" by Max Dauthendey (1909) was used as stimulus material. It was professionally recorded and spoken in a natural way by a trained, male speech therapist. The story lasted 23:32 min in total and was split into two runs of 14:32 and 9:00 min. Word onsets were determined by visual and auditory inspection of the sound waves using Adobe Audition 1.5 (www.adobe.com/).

Within the stimulus text, all nouns were identified and classified by two independent linguists (UD and RW) into the three categories of interest: singular count nouns, plural count nouns, and mass nouns. Sets of 45 nouns per category were chosen such that they were matched for their mean word form frequency according to the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Mean frequency was 68.0 per million for singular nouns, 68.7 per million for plural nouns, and 67.1 per million for mass nouns. No compounds or deverbal nouns were included. However, given the fact that target nouns appeared in a fluent speech context, they were inevitably marked for the morphosyntactic features of gender and case. Singular target nouns were not used in a generic meaning. All plural targets were unambiguously marked for plural either at the word form itself (using suffix and/or umlaut) or via syntactic context (e.g., via determiner or verbal agreement). Mass nouns were never marked for plural. Only 3 of 45 mass nouns may have also had individuating reference (e.g., *Schmuck* [jewelry], *Geld* [money]), all others referred to substances (e.g., *Gold* [gold], *Wasser* [water]) or to more abstract, nonindividuating concepts (*Musik* [music], *Armut* [poverty]). Experimental items did not appear in syntactic context forcing an alternative meaning of count nouns interpreted as mass nouns or vice versa (as in the example, "There was dog all over the street," by Jackendoff, 1991). Ratings were gathered for all target nouns from at least 18 participants per variable for familiarity, concreteness, and imageability, as these variables have been shown to influence processing of mass and count nouns (Mondini et al., 2008; El Yagoubi et al., 2006; Bisiacchi et al., 2005; Steinhauer et al., 2001). Although concreteness and imageability seem to be two closely linked measures, it has been shown that they may elicit differential effects in the processing of mass and count nouns (El Yagoubi et al., 2006). Mean familiarity ratings on a scale ranging from 1 (nonfamiliar) to 7 (highly familiar) were 6.15 for singular nouns, 5.98 for plural nouns, and 5.71 for mass nouns. Mean concreteness ratings on a similar scale were 4.86 for singular nouns, 4.84 for plural nouns, and 4.47 for mass nouns. Mean imageability ratings on a similar scale were 4.99 for singular nouns, 4.65 for plural nouns, and 4.32 for mass nouns. Results of these ratings were entered as a parametric regressor in the imaging analyses. In a post hoc analysis, we also collected rating data from 23 participants for age of acquisition (AoA). Mean ratings were 4.3 years for singular nouns, 4.8 years for plural nouns (rated as singular word forms), and 5.5 years for mass nouns. A complete list of experimental stimuli alongside with descriptive and inferential statistics of characteristic (psycho-)linguistic variables is provided in Appendix.

fMRI Data Acquisition

Scanning was performed on an 1.5-T scanner (Gyroscan Intera, Philips Medical, Eindhoven, The Netherlands) using standard gradients and a circular polarized phase array head coil. Two series of functional volumes of T2*-weighted axial EPI scans were acquired for each subject, corresponding to the presentation of the first and second part of the story. Images were aligned parallel to the AC/PC line with the following parameters: number of slices = 22, slice thickness = 5.0 mm, interslice gap = 0.55 mm, matrix size = 64 × 64, field of view = 240 × 240 mm, echo time = 50 msec, repetition time = 2.0 sec. A total of 706 functional volumes were acquired in total (Part 1: 436 volumes, Part 2: 270 volumes).

fMRI Data Analysis

MRIs were preprocessed using SPM software (SPM5; www.fil.ion.ucl.ac.uk) implemented in MATLAB 7.0 (Mathworks Inc., Sherborn, MA). After discarding the first three volumes, all images were realigned to the first image to correct for head movement. Unwarping was used to correct for the interaction of susceptibility artifacts and head movement. After realignment and unwarping, the signal measured in each slice was shifted relative to the acquisition time of the middle slice using a sinc interpolation in time to correct for their different acquisition times. Volumes were then normalized into standard stereotaxic anatomical Montreal Neurological Institute (MNI) space by using the transformation matrix calculated from the first EPI scan of each subject and the EPI template. Afterward, the normalized data with a resliced voxel size of 4 × 4 × 4 mm were smoothed with an 8-mm FWHM isotropic Gaussian kernel to accommodate intersubject variation in brain anatomy. The time series data were filtered with a high-pass cut-off of 1/128 Hz. The autocorrelation of the data was estimated and corrected for.

The expected hemodynamic response at stimulus onset for event type—singular count nouns, plural count nouns, and mass nouns—was modeled by two response functions, a canonical hemodynamic response function (HRF; Friston et al., 1998) and its temporal derivative. The latter was included in the model to account for the residual variance resulting from small temporal differences in the onset of the hemodynamic response, which is not explained by the canonical HRF alone. The functions were convolved with the event train of stimulus onsets to create covariates in a general linear model. Subsequently, parameter estimates of the HRF regressor for each of the three different conditions were calculated from the least mean squares fit of the model to the time series. Parameter estimates for the temporal derivative were not further considered in any contrast.

At group statistic level, a separate SPM5 random effects group analysis was performed by entering the contrast images for singular, plural, and mass nouns into a full factorial design. Brain activation was corrected for multiple comparisons using false discovery rate (FDR) at $p < .05$ and a voxel extent of 5 voxels. Parameter estimates (beta values) were extracted for each contrast.

RESULTS

Behavioral Results

During the postscan interview about critical story episodes, all participants were able to recall the desired detail in response to each of the ten questions. Answers to all questions were provided quickly and effortlessly (Whitney et al., 2009).

fMRI Results

The processing of plural nouns as compared with singular nouns elicited enhanced cortical responses in the left angular gyrus (BA 39; see Figure 1 and Table 1). The mass noun condition as compared with the singular noun condition elicited increased neural activation encompassing the left angular gyrus (BA 39) as well as the bilateral temporal gyri (BA 22). In both hemispheres, temporal lobe BOLD enhancements extended from the superior into the middle temporal gyri for the mass noun condition (see Figure 1 and Table 1). Thus, mass noun as well as plural noun processing was found to selectively activate the left angular region (BA 39) as compared with the singular noun condition, which was confirmed by a

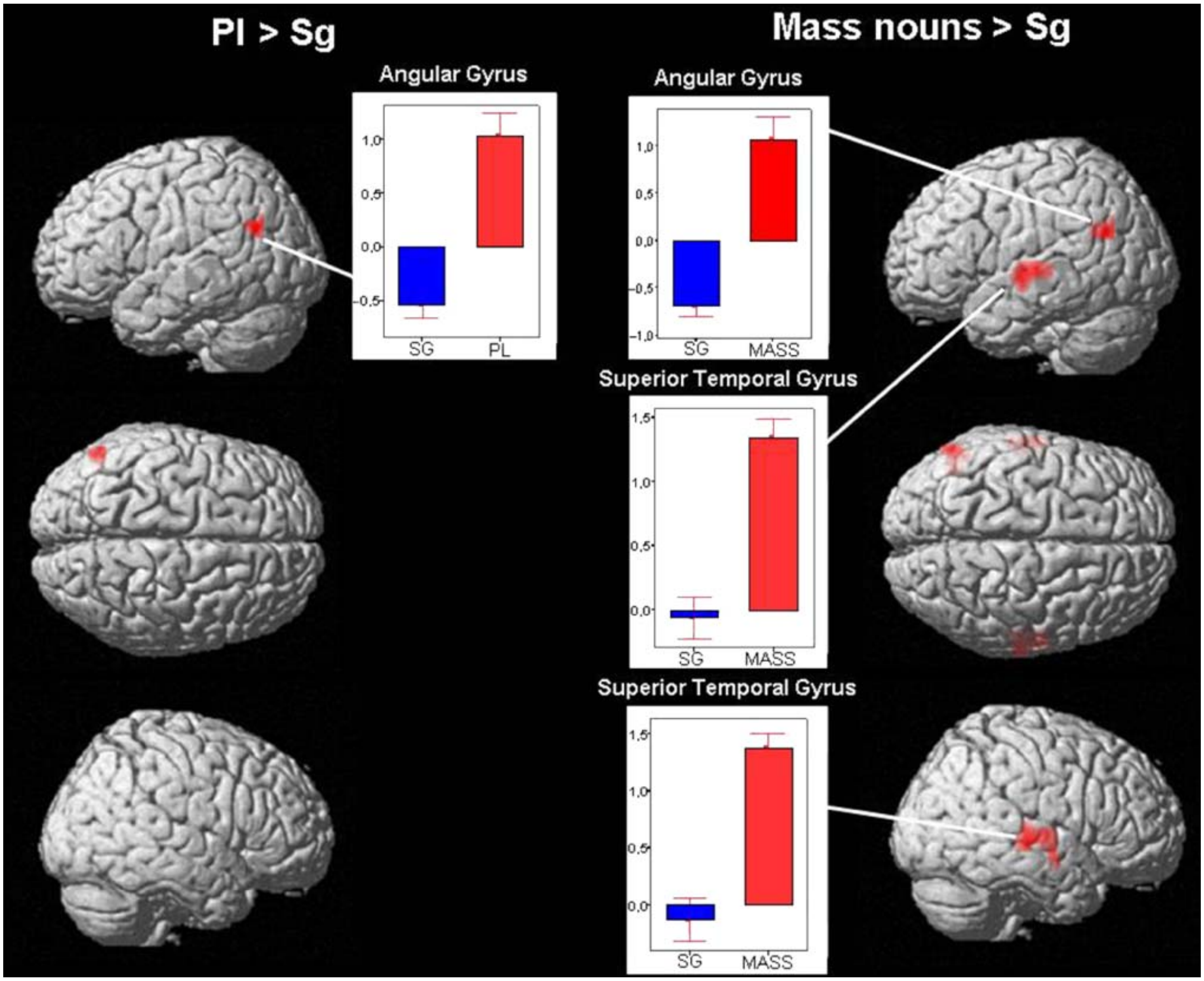

Figure 1. Cortical activations for the contrasts plural > singular (Pl > Sg) and mass > singular (Mass nouns > Sg; FDR-corrected, k = 5 voxels). The bar charts indicate beta values for singular nouns (blue) and plural nouns (red) referring to the marked cortical region.

conjunction analysis (see Figure 2 and Table 2; results also survive a family-wise error correction at $p < .05$).

There was no above-threshold activation for the contrasts of singular nouns compared with mass nouns or plural nouns. Processing of mass nouns compared with plural nouns and vice versa yielded no above-threshold activation.

Furthermore, we performed post hoc analyses for eight potentially relevant (psycho-)linguistic variables (word frequency, familiarity, imageability, concreteness, AoA, word length in syllables, animacy,[3] and information structural position) in both possible directions (e.g., more familiar vs. less familiar as well as less familiar vs. more familiar) within all three sets of experimental items separately (singular, plural, and mass nouns). For the first four of these variables, we contrasted two subsets of stimuli defined by a median split, whereas the subsets were defined by presence or absence of a dichotomous feature (one or more syllables, animate or inanimate, focus or nonfocus position) for the latter three variables. There was no evidence for any influence of these variables in any of the four crucial voxels in the left angular gyrus (see Table 2) or in the temporal lobes at the same threshold as used for our experimental analyses.

DISCUSSION

This study has been the first to directly compare brain activation for the processing of singular count nouns, plural count nouns, and mass nouns. In contrast to the majority of very constrained experimental procedures, we used a setting of coherent, natural text processing. We observed increased signal change for plural compared with singular nouns and for mass compared with singular nouns. Crucially, activation for both plural and mass nouns as compared with singular nouns overlapped in the left angular gyrus and, when directly compared,

Table 1. Activations for the Contrasts Plural > Singular (PL > SG) and Mass > Singular (Mass Nouns > SG; FDR-corrected, *k* = 5 Voxels)

		Coordinates				
	BA	*x*	*y*	*z*	*t*	*No. Voxels*
PL > SG						
Left inferior parietal cortex (angular gyrus)	39	−52	−64	28	7.24	9
Mass Nouns > SG						
Left inferior parietal cortex (angular gyrus)	39	−56	−64	24	9.38	14
		−44	−64	28	5.41	
Left superior temporal gyrus	22	−60	−16	0	8.51	27
Right superior temporal gyrus	22	56	−24	0	7.24	36
		56	−12	0	6.31	
		60	−4	−12	5.58	

Coordinates are reported in MNI space.

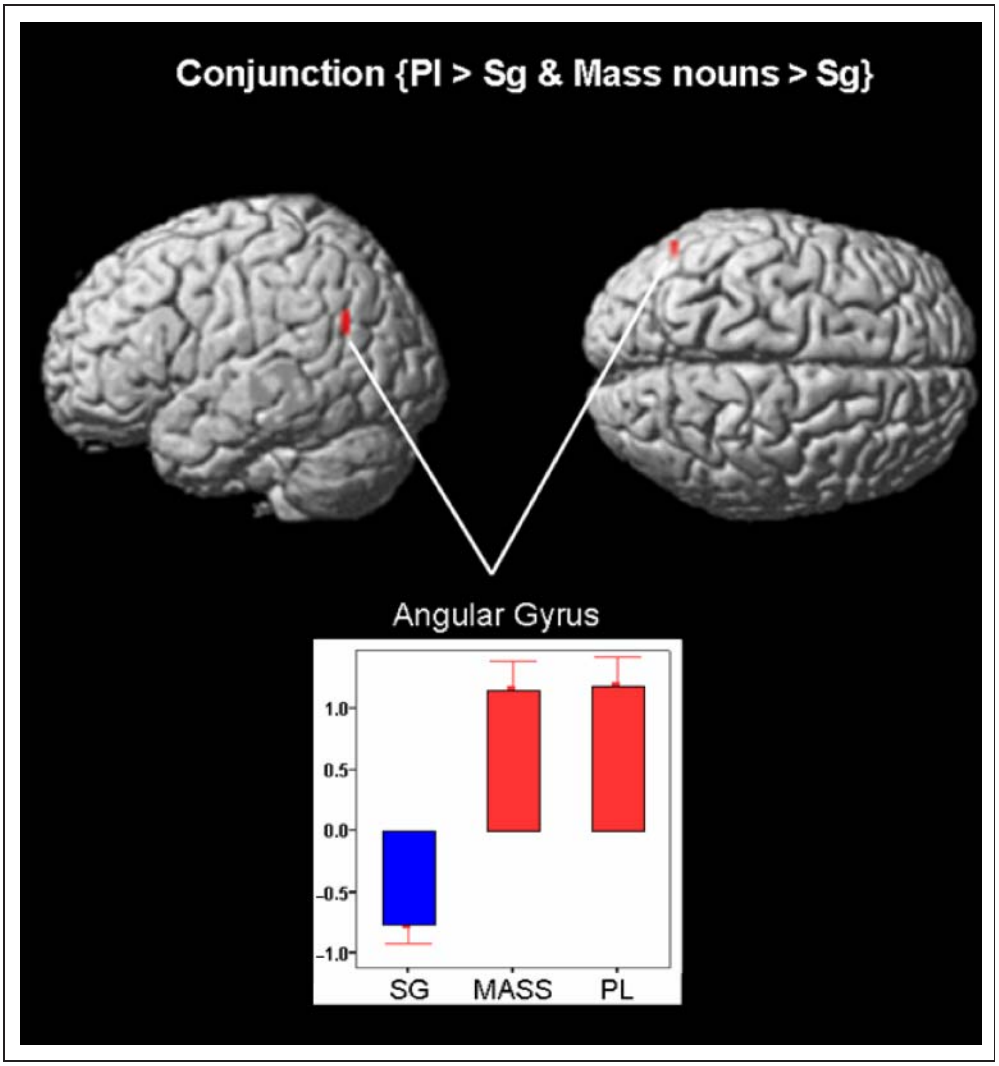

Figure 2. Conjunction analysis of brain activations for both contrasts plural (Pl) > singular (Sg) and mass nouns > singular (Sg; $p < .05$, FDR-corrected). The bar charts indicate beta values for singular nouns (blue) and mass/plural nouns (red) referring to the marked cortical region (left angular gyrus, see Table 2).

Table 2. Conjunction Analysis of Brain Activations for Both Contrasts Plural (Pl) > Singular (Sg) and Mass Nouns > Singular (Sg; $p < .05$, FDR-corrected)

		Coordinates				
	BA	*x*	*y*	*z*	*t*	*No. of Voxels*
Conjunction {PL > SG and Mass Nouns > SG}						
Left inferior parietal cortex (angular gyrus)	39	−56	−64	28	5.84	4

Coordinates are reported in MNI space.

plural and mass nouns yielded no significant difference in activation.

Processing of Plural versus Singular Count Nouns

The finding that plural nouns elicited more activation than singular nouns is consistent with the assumption that the former are more marked and/or morphologically more complex and thus pose more processing demands than the latter (Greenberg, 1966). A processing disadvantage for plural as compared with singular nouns has previously been found with behavioral measures (Mondini et al., 2009; Gillon et al., 1999). Processing an additional plural feature goes along with an increased effort and thus neural activation.

More specifically, we found stronger signal changes in the left angular gyrus for the processing of plural as compared with singular nouns. We argue that the modulation of activity within left angular gyrus was because of additional processing effort related to semantic interpretation rather than to more demanding morphosyntactic analysis. First, the fact that there was overlapping activation in the left angular gyrus for plural nouns and mass nouns makes it less likely that this activation is associated with morphological processing, given that most plural nouns were morphologically marked for plural but mass nouns were not. Second, in on-line sentence processing, a large amount of morphosyntactic processing takes place for singular as well as for plural nouns. In particular, German singular nouns—although not marked for number—are often marked for gender and case. Thus, it is likely that the processing of singular and plural nouns was related to similar effort in morphosyntactic parsing. Third, even the processing of morphologically simple items may elicit some attempts of morphological decomposition (Taft & Kougious, 2004; Taft & Forster, 1975). Fourth, the region most commonly associated with morphosyntactic processing in general and of grammatical number in particular is Broca's area (e.g., Carreiras et al., 2010) and not the angular gyrus. Fifth, although plural nouns are generally less frequent than singular nouns (e.g., Bader & Häussler, 2009), this is unlikely to be the cause of additional activation for plural nouns in this study, as target words were matched for word form frequency. Moreover, activation in the left angular gyrus was not modulated by word form frequency in our post hoc analysis. Therefore, it seems unlikely that this activity modulation was related to more demanding lexical retrieval of irregular plural word forms, which form the majority of German plural nouns (Marcus et al., 1995).

Finally, although plural nouns contained significantly more syllables and referred significantly more often to animate objects than singular nouns (see Appendix), both variables are unlikely to be causative for the modulation of angular gyrus activity, as no significant effect of these variables was observed in our post hoc analyses.

Processing of Mass Nouns versus Singular Count Nouns

The fact that mass nouns led to more extended brain activation than singular nouns can be seen as evidence against the assumption that the former are the unmarked case (Chierchia, 1998; Krifka, 1995). Rather, it adds to behavioral evidence showing that mass nouns demand more processing effort than singular nouns (Mondini et al., 2009; El Yagoubi et al., 2006; Gillon et al., 1999). Moreover, selective deficits in brain-damaged patients for mass nouns in the light of spared count nouns (Semenza et al., 1997) also seem to suggest that mass nouns—seen from a processing perspective—are the marked case.

The present results are also consistent with previous findings from EEG studies showing more distributed processing of mass nouns as compared with count nouns both within the left hemisphere (Mondini et al., 2008) and across hemispheres (Bisiacchi et al., 2005). A more specific comparison of EEG findings and the present results reveals apparent inconsistencies. Some EEG experiments yielded stronger left posterior negativity for count nouns compared with mass nouns whereas there was stronger LAN for mass nouns compared with count nouns (Mondini et al., 2008; El Yagoubi et al., 2006). However, other studies led to opposite findings, for example, stronger negative amplitudes in left or bilateral anterior regions for count nouns compared with mass nouns (Bisiacchi et al., 2005; Steinhauer et al., 2001). The latter pattern seems to be consistent with our own observation of left inferior frontal activation for singular nouns contrasted with mass nouns at a more liberal threshold as the one reported in Results. Crucially, the finding of significantly increased negative amplitudes for count nouns compared with mass nouns was restricted for tasks and time windows related to early word recognition (e.g., [visual] lexical decision and the N 150 component). It was not reported for tasks and epochs more related to semantic and/or syntactic processing (e.g., semantic categorization/semantic judgment and later EEG components), suggesting that different engagement of language-related brain areas for mass versus count nouns may be task dependent. Possibly, the paradigm and/or analyses chosen in the present experiment emphasized semantic processing rather than early word recognition. More generally, it is difficult to compare localizations found in ERP to those in fMRI studies. In summary, the differences in activation between previous ERP experiments and our own study may be because of differences in imaging methodology (ERP vs. fMRI) or experimental setup (overt, controlled decisions to single words vs. natural, automatic story listening).

Recall that the processing of mass nouns led to significantly more activation in superior temporal cortex extending into middle temporal cortex bilaterally. This pattern of activation may be interpreted in different ways (Hein & Knight, 2008). Although the present investigation did not explicitly target to disentangle at which specific level of linguistic processing mass nouns may be more demanding than singular nouns, the post hoc analyses of characteristic (psycho-)linguistic variables are informative. First, it may be argued that there was a processing difference at the level of phonological complexity. Indeed, phonological processing is known to be associated to the superior temporal lobes, bilaterally (e.g., Klein, Domahs, Grande, & Domahs, 2011; Zhang et al., 2011). However, the set of mass nouns used as target words in this study did not differ significantly in syllable length from singular nouns (mean number of syllables 1.64 and 1.56, respectively, see Appendix). Moreover, in our post hoc analyses no significant influence of syllable length has been detected in the temporal lobes. Therefore, it seems unlikely that different activation patterns resulted from phonological complexity as measured with number of syllables.

Second, significantly increased temporal activation may be related to differences in lexical retrieval. Yet, sets of stimuli were matched for word frequency. Furthermore, none of the variables potentially related to lexical retrieval like frequency, familiarity, or AoA led to any significant activation in the temporal lobes in any of the three experimental conditions. Thus, a lexical account of increased temporal activation for mass as compared with singular nouns is not very likely, too.

Third, additional activation for mass nouns in the superior temporal lobes may be because of more complex semantic processing. The mass–count distinction is potentially confounded with other aspects of semantic description, that is, concreteness, imageability, or familiarity. Nevertheless, the present findings cannot be attributed to artifacts related to these variables as ratings for concreteness, imageability, and familiarity were entered into analysis as a parametric regressor. Moreover, mass nouns typically refer to inanimate objects, whereas count nouns may refer to animate as well as inanimate objects. Indeed, in our sets of target items, 10 of 45 singular nouns but no single mass noun were animate (see Appendix). However, in our view, it seems not particularly plausible that the different patterns of activation observed were because of the difference in animacy. Processing of animacy has been attributed to areas different from those observed in this study both within (left inferior temporal cortex: Bell, Hadj-Bouziane, Frihauf, Tootell, & Ungerleider, 2009; Mitchell, Heatherton, & Macrae, 2002; right middle temporal cortex: Leube, Erb, Grodd, Bartels, & Kircher, 2001; left posterior superior temporal cortex: Grewe et al., 2007; Grossman et al., 2002) and outside (Mitchell et al., 2002) temporal cortex. In fact, in our data set animacy did not significantly influence temporal activation, making this variable no candidate to explain the different activation patterns for mass nouns and singular nouns. A tentative possible explanation in terms of semantic processing is offered by a model relating bilateral anterior superior temporal cortex to semantic integration (Vigneau et al., 2011; Jung-Beeman, 2005; Kircher, Brammer, Tous Andreu, Williams, & McGuire, 2001). One aspect of semantic integration may be related to information structure. In this study, mass nouns appeared much more often in focus position than in nonfocus position (40:5). The relationship was somewhat less biased for singular and plural count nouns (both 32:13, see Appendix). One may speculate that words appearing in focus position cause some greater costs in semantic integration than words in nonfocus positions. Moreover, focus and nonfocus positions are associated with different types of prosody (Gussenhoven, 2004). For the processing of linguistic prosody, like contrastive stress and intonation, a number of studies revealed involvement of the superior temporal gyrus, bilaterally (Ischebeck, Friederici, & Alter, 2008; Meyer, Steinhauer, Alter, Friederici, & von Cramon, 2004). Yet, our post hoc analyses revealed that bilateral superior temporal activation for mass nouns, as observed in this study, was not related to the appearance in focus position. According to Jung-Beeman (2005), the repair of ungrammatical sentences may also lead to increased effort in semantic integration. Consistent with this assumption, Meyer, Friederici, and von Cramon (2000) found activation in bilateral peri-sylvian regions including superior temporal cortex when participants had to mentally repair grammatical errors in sentences (including case, gender, and number disagreement), requiring the construction of new semantic relations. In a similar vein, it may be assumed that semantic nonsingularity in words that are morphosyntactically singular (i.e., mass nouns) also causes some kind of "number disagreement" and thus induces higher costs in semantic integration compared with words that are consistent in semantic and morphosyntactic number. Further research should address this possibility, for instance, by examining plural mass nouns.

Mass nouns elicited more signal change in the left angular gyrus compared with singular nouns. Could their specific activity modulation be because of any other confounding property? In fact, mass nouns were characterized by a significantly lower imageability and a significantly higher mean AoA (see Appendix). May the effect observed in the left angular gyrus be an artifact related to one of these two variables? First, significant differences of imagebility and AoA were only found for mass nouns compared with singular nouns, whereas there was no significant difference of these variables for plural nouns as compared with singular nouns. Consequently, left angular gyrus activation observed for the contrast between plural and singular nouns (see above) can probably not be explained by imagebility and AoA. Second, in our post hoc analyses, we found no significant within-category effects of imagebility or AoA within the angular gyrus. Third, with respect to AoA, involved brain areas seem to depend on modality and language. Although Weekes, Chan, and Tan (2008) found left inferior parietal activity modulation related to AoA for reading in Chinese, these findings were dissimilar to those observed by Fiebach, Hernandez, and colleagues (Hernandez & Fiebach, 2006; Fiebach, Friederici, Müller, von Cramon, & Hernandez, 2003) for visual and auditory word processing in German. Crucially, no AoA-modulated angular gyrus activation was reported by Fiebach, Hernandez, and colleagues neither for visual word processing nor for auditory word recognition in German (the latter task being somewhat related to the one used in our own experiment). Fourth, with respect to imageability, a number of, mostly, reading-related studies have indeed shown modulation of activity in the left angular gyrus (Graves, Desai, Humphries, Seidenberg, & Binder, 2010; Bedny & Thompson-Schill, 2006; Binder, Medler, Desai, Conant, & Liebenthal, 2005; Binder, Westbury, McKiernan, Possing, & Medler, 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005), although other studies yielded differing results (Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2011; Hauk, Davis, Kherif, & Pulvermüller, 2008; Wise et al., 2000). Crucially, those studies that reported angular gyrus involvement found increased activation for high-imageability words, whereas mass nouns, as used in our study, had significantly lower imageability than singular nouns. In summary, we do not think that modulation of angular gyrus activity found in our study was an artifact of AoA or imageability.

Processing Nonsingularity

The area found to be associated with the contrast between plural and singular nouns overlaps with the one found for the contrast between mass nouns and singular nouns. We suggest that this is, in fact, no bare coincidence, but that this commonly activated region can be attributed to the same phenomenon.

What is it that makes mass and plural nouns more demanding to process than singular nouns? Both types of nouns—if compared with singular count nouns—activate overlapping regions in the left angular gyrus. As argued above and as supported by our post hoc analyses, these activations cannot be related to a number of potential other variables including frequency, AoA, familiarity, concreteness, imagebility, word length, animacy, or information-structural position. Rather, the present results suggest that it is their nonsingularity, which distinguishes them from singular nouns, as has been argued for on theoretical grounds by Laycock (2006), Chierchia (1998), and others. Processing of nonsingular nouns may evoke higher costs in semantic interpretation. In fact, there is accumulating evidence that the left angular gyrus plays a crucial role in semantic processing and speech comprehension (Vigneau et al., 2011; Brownsett & Wise, 2010; Seghier, Fagan, & Price, 2010; Binder, Desai, Graves, & Conant, 2009; Obleser, Wise, Dresner, & Scott, 2007). More specifically, it has been claimed that the left angular gyrus may be involved in the processing of quantity (Cattaneo et al., 2009; Rusconi et al., 2005; Göbel et al., 2001)—either via finger-based representations (Rusconi et al., 2005) or via visuospatial processes (Cattaneo et al., 2009; Hubbard et al., 2005) or as a kind of mapping hub between symbolic input and quantity representations proper (Ansari, 2008). Whatever the specific nature of angular gyrus involvement may be, it should be able to explain common activation of different types of nonsingularity—numerosity based and volume based. Common activation for different types of dimensions (e.g., numerosity, time, and space) has been demonstrated for the intraparietal sulcus (Pinel, Piazza, Le Bihan, & Dehaene, 2004; Fias, Lammertyn, Reynvoet, Dupont, & Orban, 2003; Walsh, 2003). How this relates to findings of common angular gyrus activation for different kinds of nonsingularity remains to be investigated.

APPENDIX

Table IA. Full List of Experimental Items

Condition	*Item*	*Translation*	*Frequency*	*Syllables*	*Animacy*	*Focus*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Singular	*Arbeit*	work	455	2	0	0	6.72	2.95	2.41	3.70
Singular	*Palme*	palm tree	2	2	0	0	5.78	6.25	5.95	5.78
Singular	*Dampfer*	steamboat	6	2	0	1	4.61	5.60	5.32	5.70

Table IA. (*continued*)

Condition	*Item*	*Translation*	*Frequency*	*Syllables*	*Animacy*	*Focus*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Singular	*Glocke*	bell	0	2	0	1	5.39	6.35	5.95	4.13
Singular	*Meer*	sea	56	1	0	1	6.28	6.00	5.91	4.22
Singular	*Schiff*	ship	52	1	0	0	6.00	5.95	5.64	3.35
Singular	*Wald*	forest	51	1	0	1	6.39	5.95	5.41	4.04
Singular	*Stiel*	peduncle	2	1	0	1	4.94	4.25	4.45	5.09
Singular	*Erde*	ground	180	2	0	1	6.61	5.45	5.18	3.17
Singular	*Schatten*	shadow	48	2	0	1	6.11	4.40	3.23	5.09
Singular	*Person*	person	53	2	1	0	6.33	3.80	4.32	5.87
Singular	*Herzen*	heart	58	2	1	1	6.83	6.05	4.95	2.13
Singular	*Hafen*	port	28	2	0	0	5.89	5.45	5.18	5.26
Singular	*Haus*	house	104	1	0	1	6.94	6.15	6.09	3.35
Singular	*Kopf*	head	201	1	1	1	6.72	5.75	5.95	2.57
Singular	*Gerüst*	scaffold	2	2	0	1	4.72	5.35	5.36	6.65
Singular	*Zug*	procession	21	1	0	0	6.67	6.35	5.55	3.70
Singular	*Gottes*	god	109	2	0	1	6.11	2.65	1.86	3.78
Singular	*Dach*	roof	25	1	0	1	6.33	5.80	5.32	3.52
Singular	*Ecke*	corner	0	2	0	1	5.72	4.00	4.14	4.04
Singular	*Haar*	hair	41	1	0	1	6.72	5.70	6.00	3.00
Singular	*Affe*	monkey	1	2	1	1	5.94	6.55	6.36	2.74
Singular	*Wort*	word	124	1	0	1	7.00	2.05	2.50	4.65
Singular	*Arm*	arm	57	1	1	1	6.67	5.95	6.18	2.30
Singular	*Brücke*	bridge	0	2	0	1	6.50	6.20	5.27	4.13
Singular	*Schal*	scarf	1	1	0	1	6.56	6.05	5.77	4.13
Singular	*Hügel*	hill	13	2	0	0	5.83	4.90	4.82	2.13
Singular	*Frau*	woman	496	1	1	0	6.89	5.60	6.23	2.48
Singular	*Ertrag*	revenue	15	2	0	1	4.39	2.10	2.32	10.48
Singular	*Schatten*	shade	48	2	0	1	6.11	4.40	3.23	5.09
Singular	*Dorf*	village	53	1	0	1	6.06	4.60	4.23	4.13
Singular	*Haut*	skin	40	1	0	0	6.83	4.85	6.04	3.52
Singular	*Gesicht*	face	87	2	1	0	6.72	5.60	6.00	3.17
Singular	*Nacht*	night	151	1	0	1	6.72	3.80	3.32	3.52
Singular	*Haar*	hair	41	1	0	1	6.72	5.70	6.00	3.00
Singular	*Haar*	hair	41	1	0	1	6.72	5.70	6.00	3.00
Singular	*Gedanke*	thought	40	3	0	1	6.44	1.90	1.59	7.17
Singular	*Strom*	stream	43	1	0	0	6.11	2.15	2.86	6.13
Singular	*Gesicht*	face	87	2	1	1	6.72	5.60	6.00	3.17
Singular	*Spalt*	gap	4	1	0	1	4.50	4.05	3.41	7.87
Singular	*Gesicht*	face	87	2	1	1	6.72	5.60	6.00	3.17
Singular	*Akrobat*	acrobat	1	3	1	1	4.44	5.15	5.05	7.43

Table IA. (*continued*)

Condition	*Item*	*Translation*	*Frequency*	*Syllables*	*Animacy*	*Focus*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Singular	*Ball*	ball	56	1	0	1	6.61	6.55	6.27	1.35
Singular	*Wald*	forest	51	1	0	0	6.39	5.95	5.41	4.04
Singular	*Figur*	figure	30	2	0	1	5.56	4.30	4.05	5.61
Mass	*Staub*	dust	19	1	0	1	5.89	4.35	4.68	5.43
Mass	*Papier*	paper	51	2	0	1	6.78	4.90	5.55	3.78
Mass	*Reis*	rice	2	1	0	1	6.33	5.95	6.45	4.91
Mass	*Wasser*	water	81	2	0	1	6.89	5.00	5.82	1.96
Mass	*Grund*	bottom	239	2	0	1	4.17	3.10	4.73	7.96
Mass	*Wasser*	water	81	2	0	1	6.89	5.00	5.82	1.96
Mass	*Luft*	air	105	1	0	1	6.72	2.40	3.32	3.96
Mass	*Geld*	money	181	1	0	1	6.83	5.45	5.32	4.04
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Armut*	poverty	14	2	0	0	5.17	3.70	2.23	8.39
Mass	*Atem*	breath	25	2	0	1	6.22	3.40	4.55	5.87
Mass	*Metalles*	metal	44	3	0	1	5.78	4.85	5.55	6.04
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Leben*	existence	457	2	0	1	6.44	2.00	2.45	5.00
Mass	*Notdurft*	nature’s call	0	2	0	1	3.50	2.60	3.18	11.61
Mass	*Aussatz*	leprosy	0	2	0	1	2.28	1.80	2.23	11.52
Mass	*Mehl*	flour	4	1	0	1	6.11	5.95	6.23	4.30
Mass	*Wasser*	water	81	2	0	1	6.89	5.00	5.82	1.96
Mass	*Freude*	joy	80	2	0	1	6.56	2.50	2.95	5.35
Mass	*Metall*	metal	44	2	0	1	5.78	4.85	5.55	6.04
Mass	*Metall*	metal	44	2	0	1	5.78	4.85	5.55	6.04
Mass	*Musik*	music	120	2	0	1	6.72	2.55	3.77	3.61
Mass	*Norden*	north	42	2	0	1	5.67	2.10	1.77	6.22
Mass	*Ehre*	honor	30	2	0	1	5.06	1.60	1.68	8.65
Mass	*Dunkelheit*	darkness	15	3	0	1	6.22	4.15	3.45	5.35
Mass	*Leben*	existence	457	2	0	1	6.44	2.00	2.45	5.00
Mass	*Sand*	sand	29	1	0	1	5.89	5.65	5.68	3.26
Mass	*Rasen*	lawn	0	2	0	1	5.78	5.65	5.73	5.26
Mass	*Schmuck*	jewelry	11	1	0	1	6.39	4.85	4.95	5.61
Mass	*Tang*	tang	1	1	0	1	3.11	4.15	4.95	10.13
Mass	*Reis*	rice	2	1	0	1	6.33	5.95	6.45	4.91
Mass	*Milch*	milk	43	1	0	1	6.72	5.60	6.18	2.74
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Weihrauch*	olibanum	1	2	0	1	4.33	4.40	5.27	9.26
Mass	*Seide*	silk	6	2	0	1	5.17	4.55	5.32	7.17

Table IA. (*continued*)

Condition	*Item*	*Translation*	*Frequency*	*Syllables*	*Animacy*	*Focus*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Mass	*Geld*	money	181	1	0	1	6.83	5.45	5.32	4.04
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Goldes*	gold	47	2	0	1	5.61	5.25	4.64	4.13
Mass	*Gold*	gold	47	1	0	0	5.61	5.25	4.64	4.13
Mass	*Einfalt*	simple-mindedness	2	2	0	0	3.28	1.55	1.59	11.61
Mass	*Gold*	gold	47	1	0	1	5.61	5.25	4.64	4.13
Mass	*Luft*	air	105	1	0	0	6.72	2.40	3.32	3.96
Mass	*Verdauung*	digestion	1	3	0	0	5.22	2.10	2.77	9.43
Mass	*Goldes*	gold	47	2	0	1	5.61	5.25	4.64	4.13
Plural	*Dörfer*	villages	11	2	0	1	6.06	4.60	4.23	4.13
Plural	*Palmen*	palm trees	1	2	0	0	5.78	6.25	5.95	5.78
Plural	*Töpfe*	pots	2	2	0	1	6.33	6.05	6.00	3.52
Plural	*Jungen*	boys	41	2	1	0	6.22	5.35	5.64	2.83
Plural	*Säcke*	sacks	0	2	0	1	5.22	5.55	5.23	4.39
Plural	*Arbeiter*	workers	239	3	1	1	5.78	4.50	5.05	5.09
Plural	*Stunden*	hours	181	2	0	0	6.67	1.95	2.68	4.91
Plural	*Bemühungen*	efforts	60	4	0	1	5.39	1.75	2.00	9.35
Plural	*Fälle*	means	34	2	0	0	5.50	1.35	2.05	7.43
Plural	*Tage*	days	386	2	0	0	6.83	2.00	2.59	3.70
Plural	*Glocken*	bells	0	2	0	1	5.39	6.35	5.95	4.13
Plural	*Bäume*	trees	23	2	1	1	6.83	6.55	6.41	1.78
Plural	*Mönche*	monks	12	2	1	0	4.83	5.80	5.27	7.87
Plural	*Ohren*	ears	24	2	1	0	5.22	6.30	6.18	2.48
Plural	*Dampfer*	steamboats	6	2	0	0	6.67	5.60	5.32	5.70
Plural	*Dutzenden*	dozens	17	3	0	1	3.89	2.40	2.23	9.17
Plural	*Jacken*	coats	0	2	0	1	6.83	5.90	6.14	3.52
Plural	*Arbeiter*	workers	239	3	1	1	5.78	4.50	5.05	5.09
Plural	*Abgeordneten*	delegates	36	5	1	1	5.33	3.85	4.68	10.48
Plural	*Hände*	hands	96	2	1	1	6.89	6.35	6.32	1.96
Plural	*Fingern*	fingers	42	2	1	1	6.78	6.45	6.23	2.22
Plural	*Schultern*	shoulders	32	2	1	1	6.61	5.80	5.95	4.65
Plural	*Jahre*	years	697	2	0	1	6.39	1.60	2.23	4.04
Plural	*Hände*	hands	96	2	1	1	6.89	6.35	6.32	1.96
Plural	*Äste*	branches	2	2	0	1	6.06	5.95	5.95	3.70
Plural	*Schultern*	shoulders	32	2	1	1	6.61	5.80	5.95	4.65
Plural	*Blättern*	leaves	19	2	0	0	6.50	6.00	6.09	2.91
Plural	*Eltern*	parents	85	2	1	1	7.00	4.80	5.50	3.09
Plural	*Brüder*	brothers	21	2	1	1	6.39	4.10	5.27	2.83
Plural	*Freunden*	friends	86	2	1	1	6.72	3.60	4.64	4.04

Table IA. (*continued*)

Condition	*Item*	*Translation*	*Frequency*	*Syllables*	*Animacy*	*Focus*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Plural	*Euter*	udders	1	2	1	1	5.11	5.60	5.64	5.78
Plural	*Maßen*	dimensions	35	2	0	1	4.50	2.15	2.18	8.57
Plural	*Beine*	legs	32	2	1	1	6.72	6.35	6.27	2.39
Plural	*Stufen*	steps	22	2	0	0	5.61	4.95	4.50	4.65
Plural	*Blumen*	flowers	29	2	1	1	6.72	6.45	6.36	1.78
Plural	*Hunde*	dogs	20	2	1	1	6.72	6.40	6.64	5.52
Plural	*Hunderte*	hundreds	19	3	0	1	5.11	2.30	2.32	5.52
Plural	*Händen*	hands	96	2	1	1	6.89	6.35	6.32	1.96
Plural	*Hunde*	dogs	20	2	1	1	6.72	6.40	6.64	7.87
Plural	*Schatten*	shadows	48	2	0	0	6.11	4.40	3.23	5.09
Plural	*Bettler*	beggars	1	2	1	1	5.17	5.35	5.32	7.00
Plural	*Stufen*	steps	22	2	0	0	5.61	4.95	4.50	4.65
Plural	*Haare*	hairs	24	2	0	1	6.72	5.70	6.00	3.00
Plural	*Flügel*	wings	22	2	1	0	6.06	5.85	5.64	8.74
Plural	*Stunden*	hours	181	2	0	1	6.67	1.95	2.68	4.91

Frequency = wordform frequency per million according to the CELEX database; Animacy: 1 = *animate*, 2 = *inanimate*; Focus: 0 = *does not appear in focus position*, 1 = *does appear in focus position within narrative*. Values for familiarity, imageability, and concreteness are based on ratings using scales from 1 (*minimum*) to 7 (*maximum*). Within condition, words are listed in order of their appearance in the narrative. For further details, see Methods section.

Table IB. Psycholinguistic Variables Characterizing the Three Sets of Experimental Items

	Frequency	*Syllables*	*Animate Items*	*Items in Focus Position*	*Familiarity*	*Imageability*	*Concreteness*	*AoA*
Singular nouns	68.02 (100.63)	1.56 (0.59)	10/45 (22.2%)	33/45 (73.3%)	6.16 (0.73)	5.01 (1.31)	4.87 (1.35)	4.28 (1.75)
Mass nouns	67.13 (99.46)	1.64 (0.61)	0/45 (0.0%)	40/45 (88.9%)	5.72 (1.07)	4.21 (1.41)	4.45 (1.37)	5.54 (2.50)
Plural nouns	68.71 (123.12)	2.20 (0.59)	23/45 (51.1%)	32/45 (71.1%)	6.09 (0.76)	4.86 (1.66)	4.96 (1.50)	4.77 (2.25)

Frequency = wordform frequency per million according to the CELEX database. Values for familiarity, imageability, and concreteness are based on ratings using scales from 1 (*minimum*) to 7 (*maximum*). Values for frequency, number of syllables, familiarity, imageability, concreteness, and AoA are indicated as mean per condition. Standard deviations are indicated in brackets. For further details see Methods section.

Table IC. Statistical Comparisons between Conditions

	Singular–Plural	*Singular–Mass*	*Plural–Mass*	*Test*
Frequency	.977	.966	.947	*t* Test
Number of syllables	**.000**	.538	**.000**	Mann–Whitney–*U* Test (exact)
Animacy	**.005**	**.001**	**.000**	Mann–Whitney–*U* Test (exact)
Focus	1.000	.104	**.063**	Mann–Whitney–*U* Test (exact)
Familiarity	.658	**.027**	**.065**	*t* Test
Imageability	.625	**.007**	**.050**	*t* Test
Concreteness	.754	.152	.096	*t* Test
AoA	.247	**.007**	.128	*t* Test

Indicated are two-sided p values not corrected for multiple testing. All comparisons that are significant at the $p \leq .05$ level are highlighted in **bold**.

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Notes

1. In some languages, there are other possible values as well, such as dual, trial, or paucal (Corbett, 2000).
2. The use of the term markedness in an unduly broad sense has been criticized by Haspelmath (2006).
3. Note that we were not able to perform analyses for animacy for mass nouns, as there were no animate mass nouns used as experimental items.

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