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Categorizing with gender: Does implicit grammatical gender affect semantic processing in 24-month-old toddlers?



Susan C. Bobb*, Nivedita Mani

"Language Acquisition" Junior Research Group, Georg-August-Universität Göttingen, 37073 Göttingen, Germany

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ABSTRACT

The current study investigated the interaction of implicit grammatical gender and semantic category knowledge during object identification. German-learning toddlers (24-month-olds) were presented with picture pairs and heard a noun (without a preceding article) labeling one of the pictures. Labels for target and distracter images either matched or mismatched in grammatical gender and either matched or mismatched in semantic category. When target and distracter overlapped in both semantic and gender information, target recognition was impaired compared with when target and distracter overlapped on only one dimension. Results suggest that by 24 months of age, German-learning toddlers are already forming not only semantic but also grammatical gender categories and that these sources of information are activated, and interact, during object identification.

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Introduction

Recent research suggests that by the time children are 3 years old, they can use overt grammatical information, such as determiners, to establish reference in a sentence context and that this ability may emerge as early as 25 months (Dutch: Johnson, 2005; but see Van Heugten & Johnson, 2011; Spanish: Lew-Williams & Fernald, 2007; French: Van Heugten & Shi, 2009). Determiners are words such as the English article *the*, and in many languages the determiner is marked for gender (e.g., masculine, feminine, neuter) and identifies the gender of a following noun. Studies such as Gerken and McIntosh (1993) further show that violating expected determiner–noun sequences impairs sentence

* Corresponding author. Fax: +49 551 39 12496.

E-mail address: sbobb@uni-goettingen.de (S.C. Bobb).

comprehension (see also Kedar, Casasola, & Lust, 2006; Zangl & Fernald, 2007). All of these studies point to a child's increasing awareness of co-occurring patterns between words in a sentence, which the child may then use to extract and acquire grammatical categories (Mintz, 2003). Around the same age, children are also refining their sensitivity to categorical relationships (Mandler & Bauer, 1988). But what is happening to a child's underlying grammatical representation during this period of development? Once grammatical and semantic categories are defined, how does the gender information available to a child interact with semantic information during speech processing? In the current study, we provide evidence not only that young children are using explicit grammatical information in online sentence processing but also that implicit gender information interacts, and sometimes competes, with semantic information during object identification.

One of the difficulties in learning a morphosyntactic structure such as grammatical gender is the relatively arbitrary link between a noun and its gender. For instance, in German, *Katze* "cat" is feminine, whereas *Hund* "dog" is masculine. In some languages, the phonological ending of the noun provides a strong clue to the gender of the noun. In Spanish, nouns ending in /a/ are frequently feminine. There is some evidence that the more complex and arbitrary this relationship is, the longer children take to finally acquire grammatical gender; several observational studies indicate that children learning less transparent languages such as German show a delayed onset in using grammatical gender productively compared with children learning languages such as Spanish and that gender errors persist later in language development in the former group of children (e.g., Kuchenbrandt, 2008).

Despite these challenges, recent evidence from speech comprehension suggests that children may actually be quite precocious in their knowledge of grammatical gender. In one of the earliest studies demonstrating online sensitivity to grammatical gender in children, Johnson (2005) investigated the acquisition of gender-marked determiners in Dutch. Dutch has two genders, common (*de*) and neuter (*het*), and gender is marked on definite determiners. Dutch children (2 years 4 months [2;4 years] of age) saw two pictures and heard instructions to look at one of the two pictures. The labels for the images either overlapped in gender (same-gender trials) or did not (different-gender trials). Johnson hypothesized that on different-gender trials, the target's gender-marked determiner could be potentially informative to children in disambiguating the target picture. Johnson measured the speed with which toddlers shifted eye gazes to the target image after onset of the determiner. Results showed that for *de* words, but not for *het* words, toddlers shifted faster from the distracter to the target on different-gender trials (i.e., when gender was informative) than on same-gender or control trials (where the labels differed in gender and children heard an incorrect gender-marked determiner preceding the target label). These results suggest that, at least for common gender words, toddlers were sensitive to agreement between gender-marked determiners and nouns and could use determiners to recognize target words faster.

However, Van Heugten and Johnson (2011) failed to replicate the results of Johnson (2005) with younger Dutch children (2;0 years of age). Using a similar design, they tested two age groups on picture pairs that either shared or differed in gender. In the verbal instructions, either a real article (*de*, *het*) or nonsense article (*se*) preceded the target word. Van Heugten and Johnson measured the proportion of looking time to target and found that both 1;7- and 2;0-year-olds recognized target nouns more efficiently when preceded by real definite articles than when preceded by nonsense articles. But they found no difference in proportion of looking time to target when distracter and target shared the same gender compared with when they differed in gender. In contrast, Van Heugten and Shi (2009) did show similar results to Johnson (2005) with French toddlers at 2;1 years of age. Lew-Williams and Fernald (2007) also showed that Spanish-learning toddlers between 2;1 and 3;6 years of age used gender information on articles during online word comprehension. Van Heugten and Johnson (2011) raised the possibility that language-specific factors may explain the observed differences between these studies.

Although 24-month-old Dutch toddlers do not show sensitivity to overt gender, they may still be developing implicit knowledge about gender categories in Dutch. Recent evidence on color processing in language-mediated visual search suggests that children who do not yet have lexical labels for colors (i.e., do not correctly use or respond to color labels) still show implicit knowledge of an object's color (Johnson, McQueen, & Huettig, 2011; Mani, Johnson, McQueen, & Huettig, in press). Specifically, when hearing the name of an item that typically has a particular color (e.g., tomato), toddlers fixated an item

with the same color (red mitten) more than one with a different color (blue hat). Similar to Johnson and colleagues' explanation of color processing, we propose that although children with an emerging gender system might not (yet) use overt gender information in speech processing, the gender categories they are establishing may affect how they process speech. This possibility was one of the central questions investigated in the current study. Of particular interest to us was how implicit grammatical information about objects potentially interacts with other implicit, in this case semantic, information in a visual search task. This is particularly important because previous studies showing no effects of grammatical gender on target recognition at 2;0 years of age (Van Heugten & Johnson, 2011) may underestimate children's sensitivity to grammatical gender information by explicitly presenting them with matching or mismatching gender-marked determiners. On the other hand, explicit presentation of gender-marked articles may overestimate children's grammatical knowledge because these effects could be due to local co-occurrences (Van Heugten & Shi, 2009). In other words, sensitivity to gender could be due to a specific article form (e.g., *der* "the_{masc}") always co-occurring with a specific noun (e.g., *Hund* "dog_{masc}") and not because the child knows anything implicitly about gender.

From studies investigating toddlers' developing semantic knowledge, we know that children between 1;4 and 1;8 years of age are also rapidly forming their conceptual categories. Using an object manipulation task, Mandler and Bauer (1988) investigated toddlers' sensitivity to basic-level vs. global conceptual categories in order to test the nature of conceptual categories in child development. Basic-level categories included contrasts between items such as dogs, horses, and cars, whereas global conceptual categories contrasted items such as animals and vehicles. In Experiment 2 of their study, toddlers were given objects from different basic-level categories that were from either similar global categories (animals: dogs and horses) or different global categories (animals: dogs; vehicles: cars). Whereas 37% of 1;4- to 1;8-year-old toddlers differentiated object sets at the basic level when they were from the same global class (e.g., dogs vs. horses), 67% differentiated object sets at the basic level when items were from different global classes (e.g., dogs vs. cars). The authors concluded that it was easier for toddlers to categorize objects when these objects were from distinct global categories as opposed to same global categories. These results are consistent with the view that shared characteristics within a global class reduce the contrast between basic-level categories belonging to this global class. With respect to the current study on semantic and gender effects in object identification, these results suggest that toddlers may find it hard to correctly identify a target image when the target and distracter share a high degree of similarity such as when they are from the same semantic category. The study by Mandler and Bauer, however, was admittedly about categorization rather than word-referent mapping, and it is possible that we might not see a consistent effect of semantics when looking at word reference alone. One additional question raised by these results is the extent to which perceptual similarities mediated findings because conceptually similar objects may also be more likely to overlap in perceptual similarity.

Recent evidence from infant word recognition illustrates how perceptual and conceptual information interact, mediating potentially competitive environments. Arias-Trejo and Plunkett (2010) specifically addressed the interplay of perceptual similarity and category membership. Toddlers saw images of two familiar objects (a target and a distracter object) and heard the label for the target image. Target and distracter objects overlapped perceptually (e.g., apple–ball), semantically (e.g., dog–fish), both semantically and perceptually (e.g., cow–horse), or neither semantically nor perceptually (e.g., duck–bike). When target and distracter were from the same semantic category and also perceptually similar, toddlers failed to identify the target referent. However, when the images were from different semantic categories, there was no effect of perceptual similarity. These results raise the possibility that knowing an object's semantic category reduced competitive effects of shared perceptual similarity.

In the current study, we investigated how gender and semantic relatedness between a target and a distracter object interact. We tested children learning German, a Germanic language similar to Dutch. However, whereas Dutch uses two gender-marked forms of the definite article, German uses three gender-marked forms. In German, *der* precedes masculine nouns (e.g., *der Hund* "the dog"), *die* precedes feminine nouns (e.g., *die Puppe* "the doll"), and *das* precedes neuter nouns (e.g., *das Auto* "the car"). Adding to the German complexity, articles are also marked for case, so that nouns are not consistently preceded by the same article. There is also case syncretism, so that there is no one-to-one

mapping of forms. Whereas *der* in *Die Puppe und der Teddy sind neu* “The doll and the teddy bear are new” is an article that marks masculine gender and identifies the subject of the verb (i.e., nominative case), *der* in *Die Puppe von der Frau ist neu* “The doll of the woman is new” marks feminine gender and identifies the possessor (i.e., dative case). The additional gender form and case syncretism in German increases surface form variability, so that German incorporates a more complex gender system than has been tested to date, that is, studies investigating French, Spanish, and Dutch grammatical gender processing.

The current study extends previous work on gender processing by using a different paradigm than previously tested to ask how developing grammatical gender knowledge affects word recognition in toddlers. Concretely, rather than manipulating overt gender presentation, we examined how implicit gender affects word-referent mapping; we manipulated the grammatical gender of stimuli in relation to their semantic category to see how implicit gender and semantic knowledge interact during word processing. Toddlers saw two images of familiar objects while hearing the instruction *Guck mal!* (Look!) followed by the auditory label of one of the objects *without* the article, for example, *Fahrrad!* (Bike!). Target and distracter either matched (*der*_{masc} *Bagger*_{backhoe}–*der*_{masc} *Hase*_{rabbit}) or mismatched (*der*_{masc} *Bagger*_{backhoe}–*das*_{neut} *Auto*_{car}) for gender and either matched (*der*_{masc} *Bagger*_{backhoe}–*der*_{masc} *Trecker*_{tractor}) or mismatched (*der*_{masc} *Bagger*_{backhoe}–*das*_{neut} *Huhn*_{chicken}) for semantic category. In this way, we were able to evaluate the relative influence of gender competition on word recognition in a semantically competitive (i.e., same semantic category) and noncompetitive (i.e., different semantic category) environment. Conversely, we were also able to investigate semantic competitive effects in gender competitive (i.e., same gender) and noncompetitive (i.e., different gender) environments.

Results from the gender studies and the semantic studies reviewed here suggest that it is more effortful to recognize targets under same-gender conditions or same-category conditions. Based on these results, we predicted that the gender and semantic category similarity of the distracter and target object would influence toddler looks to target. Specifically, gender-matched and category-matched distracters should interfere with target looking. The results from Arias-Trejo and Plunkett (2010) also suggest that providing additional target-specific semantic information attenuates perceptual interference effects. We predicted a similar interaction between gender and categorical similarity where a target paired with a same-gender distracter should show less competition when the distracter is from a different semantic category than when it is from the same category as the target. Likewise, a target paired with a same-category distracter should show less competition when the distracter differs in gender than when it shares the same gender as the target.

Method

Participants

A total of 29 children (13 girls and 16 boys) at 24 months of age ($M = 24.13$ months, range = 23.20–25.20) participated in the study. We tested 9 additional children but excluded them from the final sample due to failure to look at more than 50% of the trials ($n = 3$), external distractions during the experiment ($n = 2$), or refusal to participate ($n = 4$). All children had no known visual or hearing difficulties and came from homes where German was the main language in use. All caregivers completed a subset of a German vocabulary inventory for their child (FRAKIS [Fragebogen zur frühkindlichen Sprachentwicklung]; Szagun, Stumper, & Schramm, 2009). Children received a small gift (a book) for participating in the study.

Stimuli

A female native speaker of German produced the speech stimuli in a child-directed manner. Stimuli were recorded using Adobe Audition software at a sampling rate of 44.1 kHz and were edited using Goldwave and PRAAT for subsequent acoustic measurements.

Visual stimuli were colorful digitized pictures of familiar objects selected from eight categories (vehicles, household items, kitchen objects, bedroom objects, body parts, animals, clothes, and food)

Table 1Overview of the four experimental conditions: distracters for the target *der Bagger* “the_{masc} backhoe_{masc}”.

Gender	Distracter	Translation	Category	Condition
das	Auto	car	vehicle	SC_GI
der	Trecker	tractor	vehicle	SC_GC
das	Huhn	chicken	animal	SI_GI
der	Hase	rabbit	animal	SI_GC

Note. The table illustrates sample trials across four critical conditions: semantically congruent–gender incongruent (SC_GI), semantically congruent–gender congruent (SC_GC), semantically incongruent–gender incongruent (SI_GI), and semantically incongruent–gender congruent (SI_GC).

with 2 target objects and 2 distracter objects per category. None of the items carried semantic gender information. According to the FRAKIS, a mean of 65.21% of 24-month-olds already had these items in their productive vocabulary. We paired 16 target words (8 masculine and 8 neuter) with 16 distracters (8 masculine and 8 neuter) from eight semantic categories (2 targets and 2 distracters in each category). Picture pairs either shared gender or did not, were either categorically related or not, and were crossed to create four critical conditions. All targets and all distracters appeared in each of the four conditions. Target and distracter pairings did not share phonological onset and were matched on syllable length ($p > .10$). We explicitly did not test feminine objects because most of the feminine objects known to toddlers in this age range follow a salient phonological gender rule: Words ending in a schwa are frequently feminine, for example, *die Katze* (the cat). There is a strong indication from previous research that children are sensitive to these phonological rules (e.g., Karmiloff-Smith, 1979; Pérez-Pereira, 1991), so that nouns of this nature may follow a different trajectory of acquisition. See Table 1 for an overview of the four experimental conditions, and see the Appendix for the complete list of stimuli.

Procedure

Each child sat on the caregiver's lap during the experiment facing a television monitor (92×50 cm) at eye level approximately 100 cm away from the monitor. Two cameras mounted directly above the monitor recorded the child's eye movements. A digital splitter routed synchronized signals from the two cameras to create a recording of two separate time-locked images of the child. Centrally located loudspeakers above the monitor presented auditory stimuli. The caregiver listened to music over headphones in order not to bias the child's behavior.

Design

We presented each child with 16 trials, with 4 trials in each of four critical conditions: (a) semantically congruent–gender incongruent (SC_GI) (b) semantically congruent–gender congruent (SC_GC) (c) semantically incongruent–gender incongruent (SI_GI), and (d) semantically incongruent–gender congruent (SI_GC). In each trial, children saw side-by-side images of two familiar objects. Objects remained on the screen for 5000 ms. Halfway into the trial at 2500 ms, children heard one of the objects named in a carrier phrase, for example, *Guck mal! Fahrrad!* “Look! Bike!” Importantly, the carrier phrase did not include the noun's determiner. The onset of the target label divided the trial into pre- and post-naming phases, where the pre-naming phase provided an index of children's baseline preference for either of the picture pairs that we then used for comparison with the post-naming phase. Each child saw the same 16 targets and the same 16 distracters. However, across the four versions, targets and distracters cycled through conditions to appear in each of the four conditions, so that each child saw different target–distracter pairings. Targets appeared equally often to the left and to the right, and we randomized the order of trial presentation.

Video data collected from the children were coded offline on a frame-by-frame basis at 40-ms intervals by a trained coder using LOOK (Meints & Woodford, 2008). A second skilled coder scored 10% of the participants to establish interrater reliability ($r = .99$). For each phase of a trial (i.e., before and after target word onset), we determined the proportion of time children looked at the target (PTL)

by dividing the time spent looking at the target (T) by the time spent looking at the target and the distracter (T + D). As in previous work, we began analyzing a trial's post-naming phase 233 ms after the target word onset, approximated to the next frame at 240 ms, to make sure that we included only actual responses to the auditory stimuli (Mani & Huettig, 2012; Mani & Plunkett, 2010; Swingley & Aslin, 2000). We chose to analyze a similar time frame for the pre-naming phase, so that the pre-naming phase ran from 240 to 2480 ms and the post-naming phase ran from 2740 to 4980 ms. Significant increases in a child's PTL across the two trial phases indicate that a child has correctly recognized the association between the target label and the target image (Bailey & Plunkett, 2002).

In our analyses, we included only trials where parents reported that children knew the label of target and distracter objects presented to them (FRAKIS). In the final analysis, this excluded 100 trials of the subset of 487 trials (20.53%; see below). Each child's looking times were then aggregated by condition to create a participant mean per condition.

Results

Item validation

To verify that stimuli pairings were accurately matched based on semantic closeness and visual similarity, we ran two rating studies with adults: one for semantic similarity and one for visual similarity. The entire set of stimuli pairs were presented to participants via an online questionnaire, and participants were asked to rate each stimulus pair using an 8-point ipsative scale from 0 to 7, with 0 indicating *not at all similar* and 7 indicating *very similar*. Separate experiments with different participants were run for semantic and visual similarity ratings.

Semantic ratings

Participants who did not complete the survey ($n = 2$) or who were not native speakers of German ($n = 1$) were excluded from the analysis. A total of 25 participants were included in the final analysis.

We first assessed the stability of the ratings with the goal of identifying any pairs whose ratings were not in the intended direction (see Arias-Trejo & Plunkett, 2010, for similar analyses). For each pair, we coded whether the rating was above or below the intermediate rating of 3.5. For semantically associated pairs we anticipated ratings to be above the intermediate rating of 3.5, and for semantically dissimilar pairs we anticipated the ratings to be below 3.5. All ratings were in the anticipated direction except for those items that were in the semantic category of household objects, which were judged as more dissimilar than similar (Hammer_Schlüssel: $M = 3.08$; Fenster_Bett: $M = 3.27$; Radio_Schlüssel: $M = 0.54$; Hammer_Telefon: $M = 0.96$; Fenster_Stuhl: $M = 3.12$). Therefore, we excluded these pairs ($n = 5$) from all further analyses.

We next analyzed ratings for each condition. Items in the two semantic match conditions were overall rated as being semantically similar, that is, above the intermediate rating of 3.5 (means: SC_GC = 5.08, $SD = 1.09$; SC_GI = 4.97, $SD = 1.02$). Items in the two semantic mismatch conditions were overall rated as semantically dissimilar, that is, below the intermediate rating of 3.5 (means: SI_GC = 0.48, $SD = 0.38$; SI_GI = 0.57, $SD = 0.37$). Post hoc pairwise comparisons correcting for multiple comparisons revealed significant differences between SC_GC and SI_GC ($p < .001$), between SC_GC and SI_GI ($p < .001$), between SI_GC and SC_GI ($p < .001$), and between SC_GI and SI_GI ($p < .001$). Importantly, there was no significant difference between the semantically similar SC_GC condition and the SC_GI condition ($p > .10$) or the semantically dissimilar SI_GC condition and the SI_GI condition ($p > .10$). These results confirm the original classification of the pairs of stimuli as either semantically similar or dissimilar except for the excluded items (from the household items category).

Visual similarity ratings

Participants who did not complete the survey ($n = 9$) or who were not native speakers of German ($n = 1$) were excluded from the analysis. We included 31 participants in the final analysis.

We first identified any pairs whose ratings deviated from the anticipated direction. We calculated the mean participant rating for each pair and then coded whether this mean rating was above the intermediate rating of 3.5 (perceptually similar) or below the intermediate rating of 3.5 (perceptually dissimilar). All of the 64 pairs were below the intermediate rating except one, indicating that participants judged the items as more perceptually dissimilar than similar. One pair, cookie–ice cream, had a mean score of 4.06 and was excluded from all further analyses.

We next analyzed visual similarity ratings for each condition. Items in all four conditions were overall rated as being visually dissimilar, that is, below the intermediate rating of 3.5 (means: SC_GC = 1.94, $SD = 0.95$; SI_GC = 1.13, $SD = 0.75$; SC_GI = 1.78, $SD = 0.92$; SI_GI = 1.49, $SD = 0.83$). We compared mean scores in each condition with chance by running a one-sample t test on each mean with the intermediate score of 3.5 as the test value. Ratings in all four conditions differed significantly from the intermediate rating correcting for multiple comparisons (SC_GC: $t(1, 30) = -9.13$, $p < .001$; SI_GC: $t(1, 30) = -17.59$, $p < .001$; SC_GI: $t(1, 30) = -10.35$, $p < .001$; SI_GI: $t(1, 30) = -13.43$, $p < .001$). Target and distracter items were not rated as perceptually similar in any of the four conditions tested.

Based on the two rating experiments, we analyzed the toddler data after excluding the five semantically dissimilar item pairs and the one visually similar pair. We present this more conservative analysis here. Importantly, we also ran the same analyses on the entire data set and found the identical pattern of results.

Main analysis

A 2 (Naming Phase) \times 2 (Gender) \times 2 (Semantics) repeated-measures analysis of variance (ANOVA) showed a significant main effect of naming, $F(1, 28) = 42.22$, $p < .001$, $\eta_p^2 = .60$. The main effect of naming confirmed toddlers' increased looks to target from pre-naming to post-naming (pre-naming: $M = .45$, $SE = .015$; post-naming: $M = .58$, $SE = .012$). No other main effects were significant ($F_s < 1$). There was a significant interaction effect between naming and semantics, $F(1, 28) = 4.28$, $p < .05$, $\eta_p^2 = .13$, as well as a nearly significant interaction among naming, gender, and semantics, $F(1, 28) = 3.76$, $p = .063$, $\eta_p^2 = .12$.

Follow-up pairwise comparisons on the marginal interaction of naming, gender, and semantics examined the naming effect for each condition by comparing the proportion of looks to target during the pre-naming phase with that during the post-naming phase. Indeed, it is standard in the literature to first establish that toddlers identified the target by testing whether they exhibited a naming effect in each condition, with an increase in target looking from pre- to post-naming phase (Arias-Trejo & Plunkett, 2010; Mani & Plunkett, 2010; Swingley & Aslin, 2000). Analyses adjusted for multiple comparisons confirmed that children looked more to target during the post-naming phase (i.e., after the target was labeled) than during the pre-naming phase in the following conditions: SI_GC, $t(28) = -4.95$, $p < .001$, $r = .68$; SC_GI, $t(28) = -4.13$, $p < .001$, $r = .62$; SI_GI, $t(28) = -4.56$, $p < .001$, $r = .65$. However, we did not find a significant difference in proportion of target looking from pre- to post-naming in the SC_GC condition when target–distracter pairs were selected from the same semantic and gender category ($p > .10$). Fig. 1 shows the mean PTL from pre- to post-naming for each condition.¹

Our main goal was to evaluate the influence of grammatical gender knowledge and semantics on word recognition. Therefore, planned comparisons using paired-sample t tests investigated whether the size of the naming effect changed in each condition. The naming effect was computed as the difference in the proportion of target looking (PTL) between the pre- and post-naming phases for each condition (PTL post-naming – PTL pre-naming). Results showed that in the gender congruent condition, where the gender of target and distracter matched, there was a significant semantic category effect, with increased looks to target in the semantically incongruent condition compared with the semantically congruent condition, $t(28) = -2.42$, $p < .05$, $r = .42$. However, in the gender incongruent

¹ A one-way ANOVA on the pre-naming phase found no main effect of condition, $F(3, 84) = 1.192$, $p = .318$, $\eta_p^2 = .041$. None of the pairwise comparisons between pre-naming conditions was significant (all p s $> .50$).

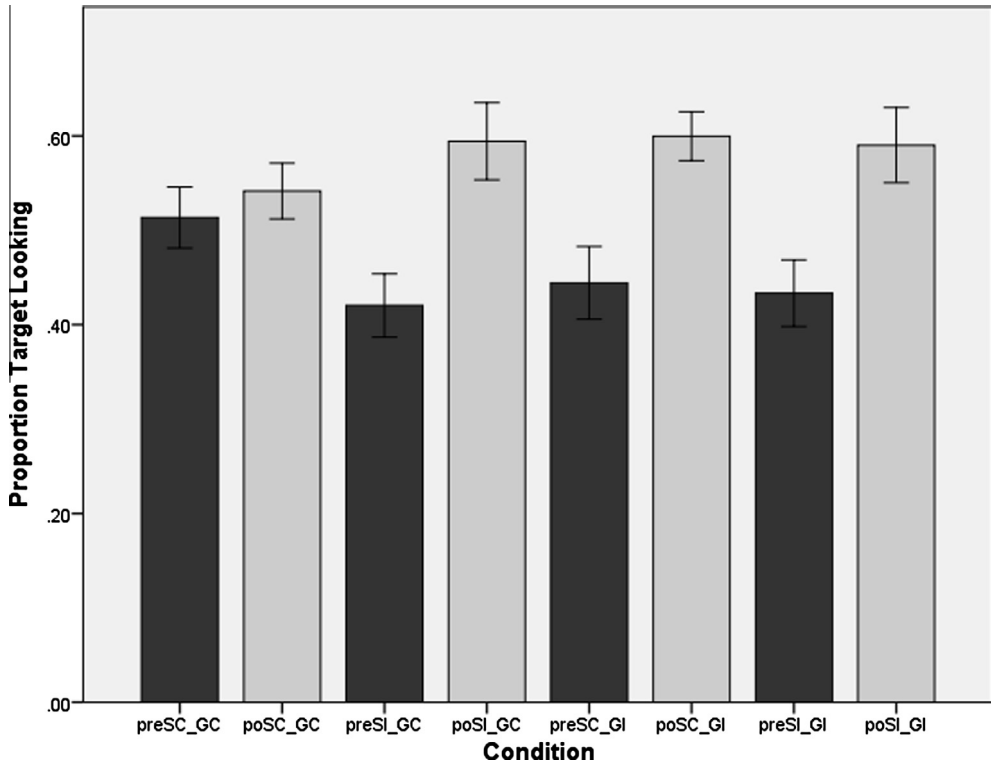


Fig. 1. Mean (± 1 SE) PTL in the pre-naming (pre) and post-naming (po) phases for each of the four conditions: semantically congruent–gender congruent (SC_GC), semantically incongruent–gender congruent (SI_GC), semantically congruent–gender incongruent (SC_GI), and semantically incongruent–gender incongruent (SI_GI) target–distracter pairings.

condition, where the gender of the target and distracter mismatched, there was no effect of semantic category ($p > .10$). A similar pattern emerged for gender; for semantically congruent items, where the semantic category of the target and distracter matched, there was a significant gender effect, with increased looks to target in the gender incongruent condition compared with the gender congruent condition, $t(28) = -2.45$, $p < .05$, $r = .42$. There was no effect of gender category for the semantically incongruent condition where the semantic category of the target and distracter mismatched ($p > .10$). These results suggest that under competitive environments in one condition (i.e., when target and distracter gender match or when target and distracter semantics match), differences in the other condition aid target recognition.²

We also analyzed the effect of target gender, whether masculine or neuter, on the size of the naming effect between conditions to explore the possibility that differences in gender may affect the rate of acquisition of a given gender category and the possible access to syntactic gender categories during word recognition. A 2 (Target Gender) \times 4 (Condition) factorial ANOVA revealed a significant main effect of condition, $F(3, 111) = 2.906$, $p < .05$, $\eta_p^2 = .073$. The main effect of gender and the interaction between gender and condition were nonsignificant ($ps > .10$). The lack of an interaction with gender in particular suggests that the gender of the target word has no effect on the size of the naming effect.

² Note that an identical pattern was found on the entire data set: SC_GC vs. SI_GC, SC_GC vs. SC_GI, $ps < .05$; SI_GC vs. SI_GI, SI_GI vs. SC_GI, $ps > .10$.

Finally, given the potential relationship between semantic and perceptual properties of objects, we further examined the effect of perceptual overlap on the semantic and gender effects. Although all items were judged as more dissimilar than similar (i.e., below the intermediate value of 3.5, with $M < 2.00$ in each condition), it is nevertheless possible that differences in perceptual similarity between conditions could be affecting our results. Post hoc pairwise comparisons adjusted for multiple comparisons showed that, in the crucial comparison where we found a gender difference, there was no difference in perceptual similarity; for semantically congruent items, there was no significant difference in perceptual similarity between gender congruent and gender incongruent items (means: $SC_{GC} = 1.92$; $SC_{GI} = 1.78$; $p = .48$). In contrast, in the comparison where we found a semantic difference, there was also a significant difference in perceptual similarity; for gender congruent items, semantically congruent items were perceptually more similar than semantically incongruent items (means: $SI_{GC} = 1.13$; $SC_{GC} = 1.94$; $p < .001$). These findings leave open the possibility that overlap in perceptual similarity, and not semantic category, influenced our semantic congruency effects. It is important to note, however, that semantic similarity effects similar to those in our study were found by Arias-Trejo and Plunkett (2010) also when controlling for perceptual similarity. We note, furthermore, that untangling the relative contribution of perceptual similarity vs. semantic similarity does not affect our claim about the observed gender effects in our study. In other words, the implicit gender effect found in the current study cannot be explained by differences in perceptual similarity between gender congruent and incongruent pairs.

Discussion

Our results provide support that 24-month-old toddlers already access both implicit semantic and gender information during the processing of familiar words. Furthermore, it appears that toddlers can use implicit information to navigate competitive environments. When target and distracter overlapped in either semantic or grammatical information—making object identification more difficult (e.g., Johnson, 2005)—differences on the other dimension appeared to help toddlers direct their attention more rapidly to the target. That is, differences in semantic or gender category information increased only target looks when there was overlap on the other dimension. Under less competitive conditions (i.e., when target and distracter differed in gender or semantic category), additional differences on the other dimension did not facilitate target looking.

Our results also shed potential light on a pending question about the grammatical knowledge toddlers are forming. Previous studies looking at overt gender in speech processing could not rule out that local co-occurrences, rather than underlying grammatical knowledge, were driving the apparent gender effects (for a discussion, see Van Heugten & Shi, 2009). Although our results cannot fully adjudicate these two possibilities, by showing gender effects in the absence of explicit gender presentation, they do suggest that 24-month-olds learning a gendered language are already forming implicit gender categories. These results raise the possibility that previous findings with overt gender presentations may have been grammatical in nature.

We note that our findings in the semantically congruent–gender congruent condition mirror those of Arias-Trejo and Plunkett (2010), who showed a similar “hit” to proportion of target looking in the condition where target and distracter shared the same category membership as well as similar perceptual characteristics. Like our results, mean PTL increases in Arias-Trejo and Plunkett’s study were around .00 for this doubly competitive condition but were between .10 and .15 for the other three conditions. Shared target–distracter item information across two implicit categories appears to create a particularly difficult environment for visual discrimination.

To what extent are children already approximating adult behavior? Results in the adult literature from picture naming tasks with bare nouns report interference effects as reflected by slower naming latencies when stimuli share the same gender (e.g., Cubelli, Lotto, Paolieri, Girelli, & Job, 2005). Cubelli et al. (2005) raised two possibilities to explain this effect. Under a competition view, once a lexical representation is activated, other items are co-activated and compete for selection on

the basis of shared grammatical information. Under an inhibitory view, when the lexical representation of the distracter is activated, in order to access the target, the distracter needs to be inhibited. When target and distracter share gender, inhibition of the gender causes additional delay in production. Cubelli et al. (2005) used a picture–word interference paradigm, and this latter inhibitory explanation hinges on the assumption that a visually presented distracter word accesses the lexicon *before* the label of the picture. In line with this assumption, previous research has shown that infants, in a similar testing situation, implicitly label images presented to them (Mani & Plunkett, 2010). The current study provided children with ample opportunity to implicitly label target and distracter images as well as extract information regarding the grammatical gender associated with these labels prior to presenting the target label—similar to Cubelli and colleagues' (2005) study—and found effects corresponding to the adult literature to date (but see Cubelli, Paolieri, Lotto, & Job, 2011).

The opportunity to implicitly label objects is important for at least one other reason. In an adult visual world eye-tracking paradigm, Dahan, Swingley, Tanenhaus, and Magnuson (2000) showed that overtly presented gender-marked articles constrain lexical candidates considered for recognition, but only for phonologically related competitors (Experiment 2). Unlike the studies mentioned earlier with young children, Dahan et al. (2000) found that in French-speaking adults, gender-marked articles alone did not restrict attention to gender-matched items (Experiment 1). In contrast, Lew-Williams and Fernald (2007) showed that Spanish-speaking adults, like children, used gender-marked articles to more quickly establish reference. Crucially, Dahan et al. (2000) limited participants' preview of the items to 500 ms to prevent them from internally labeling the pictures. Lew-Williams and Fernald (2007) used a 2000-ms preview. In our study, and in the study by Arias-Trejo and Plunkett (2010), there was a 2500-ms preview before target label onset. Van Heugten and Shi (2009) used 4000 ms. As Arias-Trejo and Plunkett (2010) argued, PTL measures may be especially sensitive to top-down category processing. Insofar as gender indexes a different sort of (grammatical) categorization, providing young children and adults with the time to label objects may maximize the interplay of these higher level lexical categorization effects. Although future research will need to tease apart the exact time course of categorization processes more specifically, it appears that gender categorization may take place post-lexically, after the lexical item has been accessed, consistent with a post-lexical gender checking mechanism (Friederici & Jacobsen, 1999).

Our findings may also speak to the role of language in thought. Recent research by Saalbach, Imai, and Schalk (2012) shows that German-speaking preschoolers use grammatical gender to evaluate the sex-specific properties of animals. The authors hypothesized that grammatical gender unconsciously biases children to extend biological properties consistent with a specific sex to all animals of that gender; for example, a giraffe (Giraffe) whose grammatical gender is feminine (die) has female properties. In a similar way, the results of our study also suggest that items that share grammatical gender (and semantic category) influence recognition of each other more than items that differ in gender. Importantly, our findings are based on participants' implicit retrieval of the grammatical gender of the simultaneously presented items because participants in our study were never presented with the article preceding the noun.

In conclusion, we have shown that German-learning toddlers retrieve both grammatical gender and semantic knowledge associated with familiar words during object identification, suggesting that children are forming not only semantic but also grammatical gender categories by 24 months of age. Particularly in light of the view that the complexity of Germanic languages hinders (productive) gender competency, these findings suggest that toddlers already know the grammatical gender of objects and extract this information during object recognition—even if they might not perfectly produce gender-marked determiners (Kuchenbrandt, 2008).

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Appendix. Stimuli used in the experiment

Gender	Item	Type	Translation	Category	Naming accuracy ^a
das	Huhn	distracter	chicken	animal	49.51
der	Hase	distracter	rabbit	animal	72.82
das	Schaf	target	sheep	animal	57.28
der	Fisch	target	fish	animal	66.02
das	Ohr	distracter	ear	body part	76.70
der	Mund	distracter	mouth	body part	74.76
das	Auge	target	eye	body part	74.76
der	Arm	target	arm	body part	77.67
das	Lätzchen	distracter	bib	clothes	52.43
der	Schuh	distracter	shoe	clothes	77.67
das	Hemd	target	shirt	clothes	32.04
der	Pullover	target	sweater	clothes	58.25
das	Brot	distracter	bread	food	72.82
der	Keks	distracter	cookie	food	79.61
das	Eis	target	ice cream	food	84.47
der	Apfel	target	apple	food	78.64
das	Messer	distracter	knife	kitchen	72.82
der	Teller	distracter	plate	kitchen	60.19
das	Glas	target	glass	kitchen	49.51
der	Becher	target	cup	kitchen	56.31
das	Telefon	distracter	telephone	object	60.19
der	Schlüssel	distracter	key	object	67.96
das	Radio	target	radio	object	30.10
der	Hammer	target	hammer	object	50.49
das	Bett	distracter	bed	room	80.58
der	Stuhl	distracter	chair	room	70.87
das	Fenster	target	window	room	44.66
der	Tisch	target	table	room	73.12
das	Auto	distracter	car	vehicle	91.26
der	Trecker	distracter	tractor	vehicle	66.99
das	Fahrrad	target	bicycle	vehicle	53.40
der	Bagger	target	backhoe	vehicle	72.82

^a Naming accuracy = percentage of 1175 children at 24 months of age who produce the word (FRAKIS: Szagun, Stumper, & Schramm, 2009).

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