Induction of Gender-like Linguistic Categories Using Noun-Marking and Blocking of Learning Trials

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Abstract. Traditional views propose that language is acquired and processed by specialized mechanisms and that language processing relies on well-defined symbolic representations that are manipulated according to rules of language. In contrast, previous research has shown that linguistic categories, like those associated with gender, can be readily induced through phonological or morphological cues or by blocking related cases (Taraban, 2004; 2012). The present experiment tested whether noun-marking and blocked learning trials would aid participants in inducing gender-like categories in an artificial language consisting of twenty-four locative phrases. Sixty English-speaking college students at a university in the United States learned eight nouns in locative phrases in an artificial language (e.g., to car = gartaik eef). Nouns were divided into two gender-like classes. Gender-marked (using -aik and -oo endings) and unmarked nouns were tested in two conditions. In one condition the phrases associated with the eight nouns were presented in random order (No Blocking). In the second condition, phrases associated with the same noun were presented in random sequence, and the learner had to input the correct locative postpositions associated with those phrases before proceeding to the next noun (Blocking). The results showed that unmarked nouns with blocking required less time to reach the experiment learning criterion (95 % correct overall) than marked nouns. Blocking resulted in significantly higher accuracy on generalization trials to new phrases, but noun marking did not. The strong blocking advantage and null effect of noun marking are discussed in terms of cognitive attention to grammatical markers.

Keywords*: linguistic categories, gender-marked nouns, encoding, cognitive resources.*

Тарабан Роман. Індукція гендерно подібних мовних категорій за допомогою навчальних тестів з маркуванням іменників та блокуванням.

Анотація. Традиційні погляди припускають, що мову засвоюють і обробляють завдяки спеціалізованим механізмам і що обробка мови спирається на чітко визначені символічні репрезентації, якими маніпулюють відповідно до правил мови. На противагу цьому, попередні дослідження показали, що лінгвістичні категорії, наприклад,

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пов'язані з гендером, можуть бути легко індуковані за допомогою фонологічних або морфологічних сигналів або шляхом блокування відповідних відмінків (Taraban, 2004; 2012). Описаний у праці експеримент перевірив, чи допоможе маркування іменників і блоковане навчання учасникам викликати гендерні категорії у штучній мові, що складається з двадцяти чотирьох локативних фраз. Шістдесят англомовних студентів університету в США вивчили вісім іменників у локативних фразах штучної мови (наприклад, to car = gartaik eef). Іменники були розділені на два родові класи. Марковані (з закінченнями -aik та -oo) та немарковані за родом іменники були протестовані в двох умовах. В одній умові фрази, пов'язані з вісьмома іменниками, були представлені у випадковому порядку (без блокування). У другій умові словосполучення, пов'язані з одним і тим же іменником, пред'являлися у випадковій послідовності, і студент повинен був ввести правильні локативні постпозиції, пов'язані з цими словосполученнями, перш ніж переходити до наступного іменника (блокування). Результати показали, що немарковані іменники з блокуванням потребували менше часу для досягнення критерію навчання (95% правильних відповідей), ніж марковані іменники. Блокування призвело до значно вищої точності в тестах на узагальнення нових фраз, а маркування іменників – ні. Сильна перевага блокування і нульовий ефект маркування іменників обговорюються з погляду когнітивної уваги до граматичних маркерів.

Ключові слова: *лінгвістичні категорії, марковані за родом іменники, кодування, когнітивні ресурси.*

Introduction

Beginning with Chomsky's (1957) influential work on the formal structure of language, generative linguists have assumed that humans possess an innate knowledge of language from birth. Knowledge of language is presumed to depend on specific brain structures – i.e., a language faculty – that govern the rules, principles, and constraints of human languages. Language acquisition is governed by a Universal Grammar that imposes innate constraints on possible syntactic structures. In the course of language learning, children conform to these universal rules, principles, and constraints. Taraban and Bandara (2017) argued that the generative language position is too restrictive regarding the linguistic constructions that it allows, and that other alternative perspectives may better address the question of what linguistic representations and operations define human language ability.

As an alternative to notions of an encapsulated language faculty and universal grammar, Bates and MacWhinney (1982; MacWhinney, 2022; MacWhinney & O'Grady, 2015) proposed that natural languages are acquired and used in the service of communication. Emergentism theory (MacWhinney & O'Grady, 2015) proposes that grammar and syntax are not innate and do not require specialized brain structures. Rather, language emerges from the

interaction of statistical regularities, sound patterns, word meanings, cognitive processes, and social contexts. A core component of emergentist theory is competition between linguistic options. Competition helps to explain language acquisition, comprehension, and production. It plays a role in L1 and L2 acquisition, and in accounting for language impairments. Competition functions through language cues, which MacWhinney (2022) defines as "an information source present in the surface structure of utterances that allows the language user to link linguistic form with meaning or function. Cues vary in their *type* (morphological, syntactic, prosodic, semantic, and pragmatic)" (p. 4).

A task faced by first- and second-language learners is to acquire linguistic categories (Maratsos & Chalkley, 1980). Although linguistic categories can be taught explicitly, as in second-language instruction, they can be acquired implicitly through exposure to instances in the language, as in the acquisition of a child's first language. Languages like German, French, and Spanish organize nouns into linguistic gender subclasses. Maratsos and Chalkley showed how masculine, feminine, and neuter categories could be induced from correlations between morphological forms appearing with nouns, for instance definite articles: *der Mann* (the man), *die Frau* (the woman). Using an artificial neural network model, Taraban et al. (1989) demonstrated how the gender, case, and number paradigm for the German definite article could be modeled as the learning of cue strengths in a neural network model. French has two gender categories: masculine and feminine. Native Russian speakers more quickly chose correct gender-marked past tense verbs when orthographic cues for gender on subject nouns were regularly marked (Taraban & Kempe, 1999). Taraban and Roark (1996) showed that non-French participants more readily learned to apply masculine and feminine adjectives (*petit* and *petite*) to French nouns when the orthographic cues in the nouns were more reliable. Other research (Taraban, 2004; 2008; 2018) using an artificial language with gender-like categories showed that linguistic categories could be induced through exposure to nouns that mark gender through phonological endings, as in a language like Polish or Ukrainian, through morphological markers, as in German, or through a combination of phonological and morphological cues, as in most Slavic languages and many Romance languages.

The present experiment is an extension of Taraban (2004). In those experiments, learning an artificial language occurred over 2–4 hour-long experimental sessions. Learning the artificial language required participants to learn the translations of English nouns into the artificial language and to select the correct morphological form of locative postpositions, which depended on the implicit gender-like category to which the nouns belonged. In previous experiments, participants were generally able to learn the noun translations

and the possible morphological forms. The primary difficulty was in associating the correct category of locative postpositions to nouns, that is, to induce the linguistic categories of the nouns.

The present experiment simplifies learning the artificial language by providing the translation of English nouns into the artificial language. The artificial language provides two cues for inducing the linguistic categories: noun endings that correlate with the linguistic categories, and morphological cues that correlate with the linguistic categories. Ukrainian, for example, marks linguistic gender with noun endings: singular masculine, no ending, as in *вітер*; feminine, *-а,-я*, as in *кава, воля*; neuter, *-о, -е*, as in *село, море*. Examples of morphological markers of gender in Ukrainian are singular pronouns that function as referents to the corresponding gender-marked nouns: *той* (masculine), *ма* (feminine), *ме* (neuter).

The Competition Model (Bates & MacWhinney (1982; MacWhinney, 2022; MacWhinney & O'Grady, 2015) rejects the claim of generative linguists regarding a language faculty and universal grammar. Rather, language emerges from the application of ordinary cognitive processes. From a cognitive perspective, attention (implicit and explicit) is critical to acquiring cues for linguistic structure. The notion of attention used here means making the intercorrelations of lexical and grammatical morphemes more available to the learner. Taraban (2004) showed that noun marking and focusing learners' attention on morphological cues both contribute to acquiring knowledge of implicit gender-like categories. It was not clear from that work whether both forms of attention interacted or operated independently. The present experiment tests the relative contributions of noun marking and morphological cues in the acquisition of gender-like linguistic categories. The research questions are as follows:

1. Can participants induce the underlying gender-like categories when the translation of English nouns into the artificial language is not required?
2. Do participants attend to both noun marking and morphological cues when learning phrases in an artificial language?
3. Do noun marking and morphological cues interact or operate independently?

Method

Participants

Sixty English-speaking undergraduate students at a Carnegie Research 1 university in the southwest of the United States participated in this study. Participants

were recruited through the Psychology Department subject pool and participated on a voluntary basis for extra credit in a psychology course. The SONA (Sona Corporation) program was used for participant sign-ups and limited participation to students with English as their primary language and minimum age of 18 years. Due to a computer coding error, demographics were not collected. Demographics from an unpublished experiment using participants recruited through the SONA system are presented here (N = 189). These demographics are representative of participants recruited through this subject pool. The mean age of the participants was 19.66 years old (SD = 2.36). For gender, 72 % identified as female, 28 % identified as male, and less than 1 % preferred not to respond. For race or ethnicity, 49 % identified as white or Caucasian; 31 % identified as Hispanic or Latino; 8 % identified as Black or African American; 5 % as Asian; and 7 % identified as Other. Forty percent were first-generation college students, and 9 % were international students.

Materials

The materials consisted of two artificial languages (see Brooks et al., 1993; Taraban, 2004, 2008, 2018 for examples). Each language consisted of 24 noun + postposition locative phrases (See Table 1). One of the languages used unmarked nouns with consonant endings across two classes; the second language marked nouns with inflection-like endings (*-aik*, *-oo*) to delineate the two noun classes. Both languages used morphological cues (*eef, rog, ast* vs *foo, ilg, tev*) to separate the nouns into two linguistic gender-like categories. Six of the nouns in Table 1 (underlined) in each language were withheld during the learning phase and provided one test of generalization during the test that followed the learning phase.

Table 1

Phrases for Two Artificial Languages, One Language Using Unmarked Artificial Nouns and the Other Language Using Marked Artificial Nouns

Unmarked-Noun Language				Marked-Noun Language		
English	*To* Probe	*From* Probe	*At* Probe	*To* Probe	*From* Probe	*At* Probe
	Class I Unmarked Nouns			Class I Marked Nouns		
scissors	zoze eef	zoze rog	zoze ast	zozaik eef	zozaik ro	zozaik ast
ball	billit eef	billit rog	<u>billit ast</u>	billaik eef	billaik rog	<u>billaik ast</u>
plane	<u>poom eef</u>	poom rog	poom ast	<u>poomaik eef</u>	poomaik rog	poomaik ast
car	garth eef	<u>garth rog</u>	garth ast	gartaik eef	<u>gartaik rog</u>	gartaik ast

Class II Unmarked Nouns				Class II Marked Nouns		
camera	kerm foo	kerm ilg	kerm tev	kermoo foo	kermoo ilg	kermoo tev
truck	teckon foo	teckon ilg	teckon tev	teknoo foo	teknoo ilg	teknoo tev
train	drame foo	drame ilg	drame tev	damoo foo	damoo ilg	damoo tev
umbrella	brol foo	brol ilg	brol tev	broloo foo	broloo ilg	broloo tev

Note. Underlined phrases were withheld during the learning phase and were used for the final test.

Table 2 consists of two types of novel phrases used during the final test. For each noun, one of the phrases was used as a hint (underlined in Table 2) that was presented in conjunction with a related phrase during the test.

Table 2
Novel Phrases Using Unmarked and Marked Artificial Nouns

English	*To* Probe	*From* Probe	*At* Probe	English	*To* Probe	*From* Probe	*At* Probe
Class I Unmarked Nouns				Class I Marked Nouns			
hat	hitab eef	hitab rog	hitab ast	maple	mupaik eef	mupaik rog	mupaik ast
helicopter	helt eef	helt rog	helt ast	drum	tomaik eef	tomaik rog	tomaik ast
bed	pidd eef	pidd rog	pidd ast	hammer	himaik eef	himaik rog	himaik ast
bus	bazo eef	bazo rog	bazo ast	baby	velaik eef	velaik rog	velaik ast
Class II Unmarked Nouns				Class II Marked Nouns			
record	rep foo	rep ilg	rep tev	woman	warnoo foo	warnoo ilg	warnoo tev
broom	bram foo	bram ilg	bram tev	lamp	lantoo foo	lantoo ilg	lantoo tev
motorcycle	mokoy foo	mokoy ilg	mokoy tev	towel	tulloo foo	tulloo ilg	tulloo tev
table	tib foo	tib ilg	tib tev	jacket	joddoo foo	joddoo ilg	joddoo tev

Note. Underlined phrases were presented as a hint for testing the related phrases.

Procedure

The experiment was conducted in a quiet room in a university building, with prior approval of the university ethics committee. The experimenter met individually with each participant and obtained consent to conduct the experiment. Each participant was randomly assigned to one of four between-

subject conditions: Unmarked-Nouns & No-Blocking; Marked-Nouns & No-Blocking; Unmarked-Nouns & Noun-Blocking; Marked-Nouns & Noun-Blocking. Fifteen participants were assigned to each of the four experiment conditions. The experiment was conducted in two parts, a learning phase and a test phase. Phrases were presented serially. On each learning and test trial, a partially translated phrase, like ***to car = garth ____?*** appeared on the computer screen. The participant typed in a locative postposition (e.g., ***eef***). During the learning phase, but not the test phase, the computer indicated whether the response was correct, and it also showed the correct response. Participants could not use written notes during any phase of the experiment.

In the learning phase, the eight nouns and their associated phrases (18 phrases total) were organized and presented in one of two ways, depending on the condition. In the Noun-Blocking condition, the eight nouns were randomized first and then the phrases for each noun were randomized. Participants were required to correctly respond to each of the phrases associated with a particular noun before proceeding to the next noun. In the No-Blocking condition, the eighteen phrases were presented in random order. Randomization of nouns and phrases in both conditions continued until the participant achieved 90% accuracy on their first responses in a block of 18 phrases. Participants were allowed up to 65 minutes for the learning phase, which was self-paced. A timer on the screen indicated how much time was left. If participants reached the 90% criterion before 65 minutes had passed, they continued to the test phase. Otherwise, they went on to the test phase after 65 minutes.

At the beginning of the test phase, participants were informed via computer that the trials would be similar to those in the learning phase but that the computer would not provide feedback about accuracy. In the first part of the test, participants were presented with the 24 phrases shown in Table 1 from their respective language in random order. These included the eighteen phrases they had studied (Studied-Old) and the six related phrases that had been withheld during study (Studied-New). For the second part of the test, participants were informed via computer that they would be presented with new phrases from the language, that because these phrases were new to them they would be provided with a hint, and that they should provide the best answer they could, even if they were unsure of their response. For example, for the novel word *broom*, the hint appeared as ***Hint: to broom = bram foo***. The test item appeared on the next line – e.g., ***from broom = bram ____?*** Participants were tested on the 32 marked and unmarked phrases in Table 2, presented in random order.

Results

There were six dependent variables: Total Learning Time, Learning Trial Accuracy, Studied-Old Accuracy, Studied-New Accuracy, Novel-Unmarked Accuracy, and Novel-Marked Accuracy. Each dependent variable was analyzed separately in a 2 (Noun Marking: Unmarked, Marked) X 2 (Blocking: No Blocking, Noun-Blocking) ANOVA, which mirrored the four between-subjects conditions in the experiment.

For Total Learning Time there was a significant effect for Blocking [$F(1, 56) = 9.50$, $p = .003$, $MSE = 270.43$], and a significant Blocking X Noun Marking interaction [$F(1, 56) = 4.63$, $p = .036$, $MSE = 270.43$]. The main effect of Noun Marking was not significant [$F(1, 56) = .003$, ns. Addressing the significant interaction, the means in Table 3 show that participants in the Noun-Blocking condition with Unmarked Nouns (32.88 min.) learned significantly faster than participants in the No-Blocking condition with Unmarked Nouns (55.11 min.). There was no difference due to blocking with marked nouns. In the analysis of Learning Trial Accuracy, there was only one significant effect: Blocking [$F(1, 56) = 81.54$, $p < .001$, $MSE = .012$]. The effects for Noun Marking [$F(1, 56) = .389$, ns] and Blocking X Noun Marking [$F(1, 56) = .856$, ns] were not significant. (See Table 3). In summary, there was a significant benefit to participants when learning phrases in a noun-blocked fashion (i.e., they could not advance to the next noun without achieving 100% accuracy on the postpositions for the current noun). There were no significant effects for noun marking (i.e., using inflection-like noun endings, *-aik* and *-oo*, to signal gender-like linguistic categories).

Table 3
Mean total (SD) learning time and accuracy for learning trials

	Total Learning Time (minutes)		Learning Trial Accuracy	
	Blocking Type			
Noun Marking	No Blocking	Noun Blocking	No Blocking	Noun-Blocking
Unmarked	55.11 (12.42)	32.88 (15.99)	.44 (.15)	.73 (.05)
Marked	45.74 (18.11)	41.79 (18.54)	.45 (.14)	.68 (.06)

An analysis of accuracy for Studied-Old phrases showed only one significant effect: Blocking [$F(1,56) = 7.46$, $p = .008$, $MSE = .033$]. The effects for Noun Marking [$F(1, 56) = .871$, ns] and the Blocking X Noun Marking interaction

[$F(1,56) = .927$, ns] were not significant. (See Table 4). The analysis of accuracy for Studied-New phrases showed a similar pattern of effects: Blocking [$F(1,56) = 8.14$, $p = .006$, $MSE = .078$], Noun Marking [$F(1,56) = 2.15$, ns], and the Blocking X Noun Marking interaction [$F(1,56) = 1.01$, ns]. In summary, participants were significantly more accurate on Studied-Old and Studied-New phrases in the Noun-Blocking conditions. Noun Marking did not result in a learning advantage.

Table 4
Mean accuracy (SD) for studied-old and studied-new phrases

	Studied-Old		Studied-New	
	Blocking Type			
Noun Marking	No Blocking	Noun Blocking	No Blocking	Noun Blocking
Unmarked	.65 (.23)	.82 (.15)	.36 (.24)	.63 (.24)
Marked	.74 (.19)	.82 (.14)	.53 (.29)	.67 (.34)

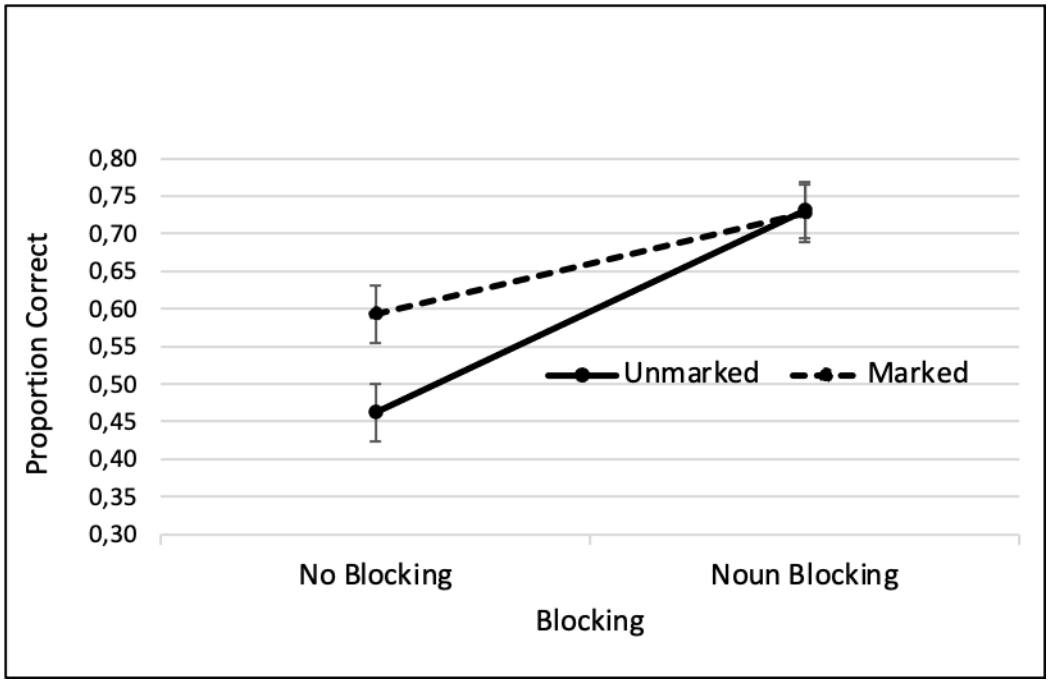
An analysis of accuracy for Novel-Unmarked phrases showed only one significant effect: Blocking [$F(1, 56) = 12.34$, $p < .001$, $MSE = .072$]. The effects for Noun Marking [$F(1, 56) = 1.37$, ns] and the Blocking X Noun Marking interaction [$F(1, 56) = 1.67$, ns] were not significant. (See Table 5). The analysis of accuracy for Novel-Marked phrases showed a similar pattern of effects: Blocking [$F(1, 56) = 10.45$, $p = .002$, $MSE = .074$], Noun Marking [$F(1, 56) = .106$, ns], and the Blocking X Noun Marking interaction [$F(1, 56) = .740$, ns]. In summary, participants were significantly more accurate on Novel-Unmarked and Novel-Marked phrases in the Noun-Blocking conditions. Noun Marking did not result in a learning advantage.

Table 5
Mean accuracy (SD) for novel-unmarked and novel-marked test phrases

	Novel-Unmarked		Novel-Marked	
	Blocking Type			
Noun Marking	No Blocking	Noun Blocking	No Blocking	Noun Blocking
Unmarked	.40 (.28)	.74 (.29)	.44 (.24)	.73 (.31)
Marked	.58 (.21)	.73 (.28)	.53 (.22)	.69 (.31)

Because of the consistency of effects across the analyses of test measures, the mean accuracy across the four test variables (Studied-Old, Studied-New, Novel-Unmarked, and Novel-Marked) was calculated, analyzed, and graphed in order to convey a clear description of the overall outcome.

Figure 1
Overall Mean Test Accuracy by Blocking and Noun Marking



Note. Data points show the mean of four variables: Studied-Old, Studied-New, Novel-Unmarked, and Novel-Marked. Error bars show standard error.

Figure 1 shows that in the noun blocking conditions, noun marking did not have an effect. However, in conditions of no noun blocking, the marked-noun condition trended toward higher accuracy than the unmarked-noun condition. However, the apparent difference between unmarked and marked nouns in the no-blocking condition was not statistically significant in any of the preceding analyses.

Discussion

Addressing the first research question, *Can participants induce the underlying gender-like categories when the translation of English nouns into the artificial language is not required*, the results showed significant effects for Studied-Old phrases and significant generalization effects for Studied-New, Novel-Unmarked, and Novel-Marked phrases. Therefore, the findings indicated that

participants do not need to learn noun translations in order to induce the underlying gender-like noun categories.

The second research question asked *Do participants attend to both noun marking and morphological cues when learning phrases in an artificial language?* The statistical analyses showed significant effects only for blocking. Blocking required participants to choose the correct locative postposition for each of the phrases for a given noun during learning, before proceeding to the next noun. Therefore, attention to the syntactic paradigm associated with locatives produced robust learning effects. The effect of blocking was strong regardless of whether nouns were marked or unmarked.

The third research question asked *Do noun marking and morphological cues interact or operate independently?* An examination of Tables 3, 4, and 5 showed that in the No-Blocking conditions, Marked Nouns showed higher accuracy than Unmarked Nouns. An examination of the No-Blocking effects in Figure 1 shows the same effect. The consistency of the advantage of marked vs unmarked nouns in evoking the correct locative postposition suggests that noun marking may have had an effect, however, the effect may have been reduced because participants did not need to translate the English nouns, nor orally speak the nouns or input the nouns, as part of their responses in this experiment.

There are several limitations in the present study. Given that this university is an Hispanic-serving institution and that many of the participants were first-generation college students (based on our representative demographics), it will be important in future studies to administer a language-use inventory to assess participants' native language and their knowledge of a second language and home use of a second language. Because we do not know which participants were mono-lingual English speakers and which were multi-lingual, it is not clear how to generalize these results to specific populations. Finally, morphological and noun cues were perfectly reliable markers of their respective gender-like categories. Natural languages, however, have exceptions to rule-like relationships between cues and categories. This aspect of natural languages was not tested in the present experiment. Finally, requiring participants to more actively process the nouns in the experiment, by requiring them to speak or input their complete responses to the computer, may amplify their attention to noun marking and provide a better metric for the relative contributions of noun marking and blocking in category induction.

Conclusions

The results of the present experiment are consistent with prior research showing the effects of orthographic noun cues on non-native (Taraban &

Roark, 1996) and native speakers (Taraban & Kempe, 1999) acquiring and processing linguistic gender categories. Other research has shown the effects of noun cues and morphological cues on the acquisition of case marking by German and Russian L2 learners (Kempe & MacWhinney, 1998). The rationale for these experiments is based on the Competition Model (Bates & MacWhinney (1982; MacWhinney, 2022; MacWhinney & O'Grady, 2015), whose underlying principles assert that knowledge of linguistic categories can be acquired through learning and processing linguistic cues associated with language operations. The role of attention to cues (Taraban, 2004) is affirmed in the present experiment. Some researchers have taken a strong position on the role of cues associated with the nouns themselves in linguistic category induction (Braine, 1987). Brooks et al. (1993), for instance, concluded that "without some similarity relation (phonological or semantic) among a subset of class members, word classes are difficult, if not impossible, to learn" (p. 92). The results here and elsewhere (Taraban, 2004; 2008; 2018) show that noun blocking, without noun marking, is sufficient for linguistic category induction.

The present results suggest several questions for future research that have not yet been addressed. One question is whether children acquiring richly inflected languages, like Polish and Ukrainian benefit from noun marking and blocking to the same extent as non-native language learners and adult second-language learners. Another question is whether native Polish and Ukrainian adult language learners would show the same pattern of effects as shown here with English-speaking participants.

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