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Nameability of Spatial Locations and Category Learning in Children

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Abstract. What is the relationship between the mental lexicon and categorization? Many studies show that the names of objects speed up category learning. Our previous experiment demonstrated that the names of an object feature's location also help while learning rules of categorization. In the present experiment, we evaluated the manifestation of this effect in ontogenesis, having compared the process of development of new concepts in 7- and 9-year-old children. Participants were supposed to learn to distinguish between two groups of aliens by signs on the foot. We varied the location of signs on the silhouette of the foot. In the high nameability condition, signs were located in places on a foot silhouette that were more nameable (e.g., "heel"). In the low nameability condition, signs were located in places without common names (e.g., "Achilles' tendon"). The category rule included relevant places for signs. We found that 9-year-old participants were more successful in learning new categories in the high nameability condition than in the low nameability condition. However, 7-year-old participants did not demonstrate differences in the two conditions. These results are discussed in relation to the development of the ability to form new categories in the course of ontogenesis.

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Introduction

Why are some new categories easier to learn than others? One possible important factor is names. For example, if it is easier to distinguish between two groups of people by the shape of the nose than by the shape of lips, then perhaps one explanation is that the representation in the language of names for various shapes of the nose is higher than the representation of names for the shapes of the lips. Having a large number of names in the category facilitates this category learning (Kotov & Kotova, 2018).

According to a recent study, it was shown that even in the absence of knowledge about categories and the same perceptual distinguishability of features, the ease of naming the feature values (for instance, the color or shape of an object's part) influences category learning (Zettersten & Lupyan, 2018): participants were faster in finding a categorization rule in the condition with high nameability of the parts of an object than in the condition with low nameability. The authors explain the results by the fact that the names of the parts or features of the object, both relevant and irrelevant, help participants to test hypotheses about the categorization rule: finding the parts, isolating them from other parts, and remembering the results of hypothesis testing.

In this study, we investigate the influence of the ease of naming feature values on the learning of categorization rules by children who are 6 to 10 years old. Children often learn the category and its label, lexicalizing this category. Words affect this learning very early. Some experiments have shown that, even for infants, the category label is a marker that the items belong to the same category (Waxman & Markow, 1995; Welder & Graham, 2001; Westermann & Mareschal, 2014). Labels can facilitate category learning in school-age children and adults as feedback.

The category features we used were the locations of the pictorial signs inside an object, unlike the color/shape of object parts as in the study by Zettersten and Lupyan (2018). Knowing the location of a characteristic can increase the probability of its identification and distinguishing it from other characteristics. It is known that the names of locations and categorization of spatial relationships vary significantly in different languages (Choi, McDonough, Bowerman, & Mandler, 1999; Levinson, Kita, Haun, & Rasch, 2002). These studies have shown that differences in location names lead to differences in remembering the location of objects. Thus, names help to structure perception during learning.

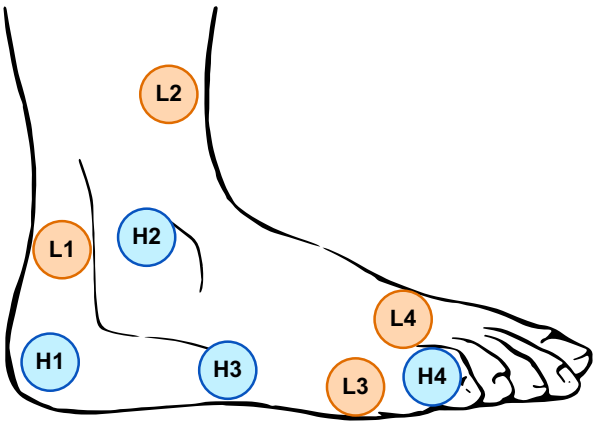

Figure 1. Locations for Low nameability (in red: L1 — Achilles' tendon, L2 — ankle, L3 — bottom of the foot, L4 — vault) and High nameability (in blue: H1 — heel, H2 — bone, H3 — sole, H4 — little toe) conditions.

In our experiment, we varied the locations of the pictorial signs on the silhouette image of a foot. In the condition with high nameability of locations (Figure 1), images of signs were located on those parts of the foot for which there are widely recognized names (for example, "heel"). In the condition with low nameability, signs were located on parts for which there are not commonly known names (for example, "Achilles' tendon").

The categorization rule required participants to establish the connection between the place of the sign and its image. Our main hypothesis was that participants would be able to learn a new category rule more successfully in the high nameability condition than in the low nameability condition. In this experiment, we prepared the material and procedure for children from the age of six.

We were interested in whether the effect of the naming of locations would be observed in children (the same as in adults in Zettersten and Lupyan's [2018] study), and if so, at what age? The formation of concepts through a search for relevant features is available for children at the age of 6 to 7 years old (Minda, Desroches, & Church, 2008), but we do not know whether the ability is also mediated at this age by the ease of verbalization of features, both relevant and irrelevant. Starting from this age, children can use names for different actions which are important for learning: describing the differences between object parts, remembering the results of hypothesis testing, keeping focus on the shift of attention between object parts, focusing on individual object parts while looking at them. Thus, our second independent variable was age — 7-year-olds versus 9-year-olds. The main dependent variable was learning efficiency. To summarize, we expected to find an effect of nameability on category learning efficiency in at least one age group (i.e., a main effect of the nameability factor with or without an interaction with age).

Method

Subjects

Sixty five children from 6 to 10 years old took part in the study. Participants were divided into two groups by age: a group of seven-year-olds (6–8 y. o., $n=39$, $M=7.56$, $SD=0.55$) and a group of nine-year-olds (9–10 y. o., $n=26$, $M=9.27$, $SD=0.45$). Participants were randomly assigned to either the high nameability condition or the low nameability condition. Parents provided informed consent for their children to participate. All procedures were approved by the research ethics board at the NRU HSE.

Material

The stimulus material consisted of an image of the foot silhouette with red signs located in different places: four places for the high nameability condition (heel, little toe, bone and sole) and four places for the low nameability condition (ankle, Achilles' tendon, bottom of the foot, vault). Participants were asked to learn to distinguish between two types of aliens by the location of the signs on their feet

Table 1. **Distribution of Feature Values in Categories**

	High Nameability		Low Nameability	
	Category A ("Gazun")	Category B ("Blicket")	Category A ("Gazun")	Category B ("Blicket")
Example 1	Locations **H1** H3	Locations **H4** H3	Locations **L1** L3	Locations **L4** L3
Example 2	Locations **H1** H2	Locations **H4** H2	Locations **L1** L2	Locations **L4** L2

Note. The values of the relevant feature are in bold print.

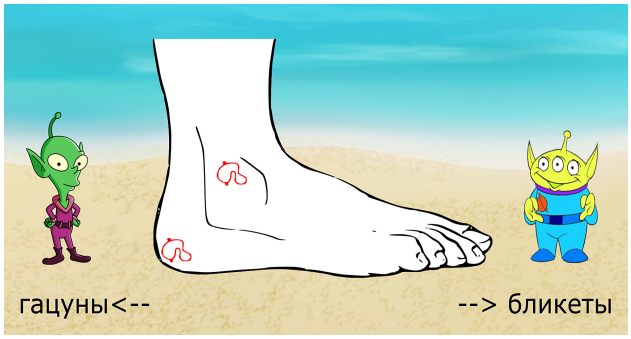

Figure 2. Example of category learning trial for the high nameability condition ("гацуны" — Gazun, "бликеты" — Blicket).

(see instructions in Appendix). In the instruction we stated, "There are two signs on the foot — one of them is important, the other one is not. The important sign is located in a specific place on the foot. The unimportant one is located in another place, however, this place is not relevant, so it does not provide any useful information. Thus, you should learn which place is important for each type of alien". The structure of the rule could be defined as follows: "if a sign is located in place 1, then this is a Gazun; if the sign is located in place 2, then this is a Blicket". The category labels were presented on the screen, but the participants were not required to read them.

Two out of four places were relevant for the categorization rule, while two were not. In each trial, participants were shown two signs on the same foot silhouette (one sign on the relevant and one on the irrelevant location)

Overall, eight images (four for each category) were used in each condition. Eight trials with different images formed a block of trials and were presented in random order. The experimental session consisted of four blocks.

Procedure

Each participant was randomly assigned to one of the two conditions defined by the location of images on the foot (High and Low nameability conditions). The participants performed the standard classification task with feedback. In each trial, participants were shown one example and they were supposed to decide which group of aliens (Blickets or Gazuns) it belonged to by pressing the LEFT button or the RIGHT button. Immediately after the response, the sound feedback was presented. The response time was not limited. The presentation of the set of trials and the registration of the participants' responses were provided by the PsychoPy software (Peirce, 2008).

To estimate learning efficiency (Training Block factor), we averaged the responses within a block (0 for an incorrect response; 1 for correct). Thus, the performance at chance level corresponded to .5. A performance level above .5 meant that subjects found the rule of categorization.

Results

We used $2\times2\times4$ analysis of variance with repeated measures (rmANOVA) with Age and Nameability as between-subject and Training Block as within-subject factors. Assumption of data sphericity was not violated: Mauchly's $W=0.835$, $p=.056$. The three-way interaction was not significant: $F(3,183)=1.076$, $p=.360$, $\eta^2_p=.017$ (Table 2). The ANOVA also did not reveal a difference between age groups: $F(1,61)=1.648$, $p=.204$, $\eta^2_p=.026$. The effect of Nameability in the two groups of children was significant ($F(1,61)=23.170$, $p<.001$, $\eta^2_p=.275$).

The Training Block factor was also significant ($F(3,183)=19.896$, $p<.001$, $\eta^2_p=.246$); learning effi-

Table 2. **ANOVA's Effects**

	Sum of Squares	*df*	*Mean Square*	*F*	*p*	η^2_p
Within-Subjects Effects						
Training Block	1.4626	3	0.4875	19.90	<.001	.246
Training Block × Nameability	0.0816	3	0.0272	1.11	.346	.018
Training Block × Age	0.2229	3	0.0743	3.03	.031	.047
Training Block × Nameability × Age	0.0791	3	0.0264	1.08	.360	.017
Residual	4.4843	183	0.0245			
Between-Subjects Effects						
Nameability	2.209	1	2.2089	23.17	<.001	.275
Age	0.157	1	0.1571	1.65	.204	.026
Nameability × Age	0.460	1	0.4600	4.82	.032	.073
Residual	5.815	61	0.0953			

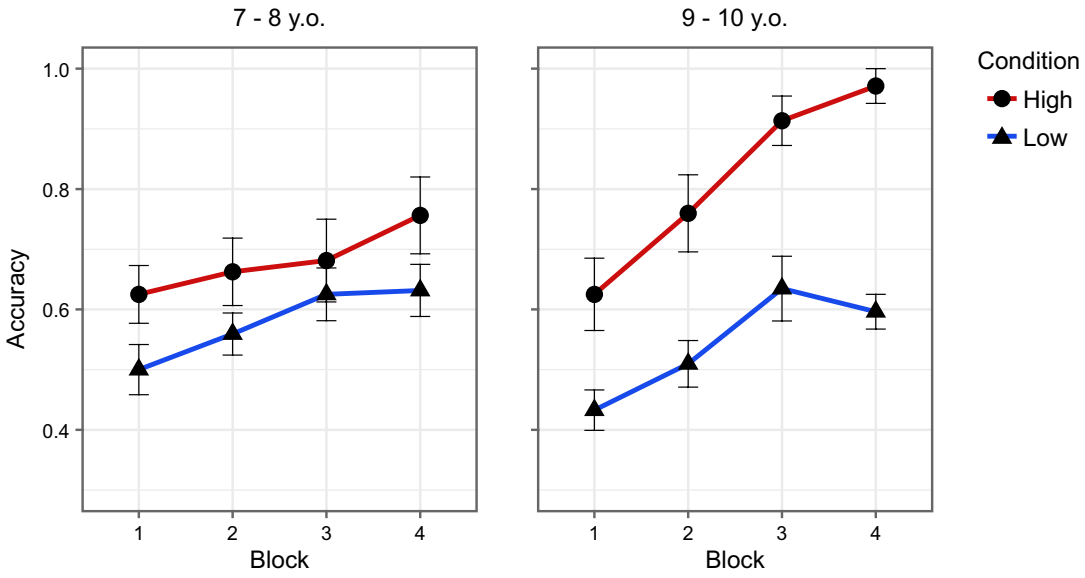

Figure 3. Average performance at each block for each age group and nameability condition. Error bars represent ±1SE.

ciency increased with the block number. ANOVA also revealed an interaction between Nameability and Age: $F(1,61)=4.824$, $p=.032$, $\eta^2_p=.073$. To analyze this interaction, we looked at the data for age groups separately (Figure 2). We did not find a significant interaction between Training Block and Nameability in 7-year-olds and 9-year-olds: $F(1,183)=1.11$, $p=.346$, $\eta^2_p=.018$. The Training Block factor was significant in each age group: performance was higher at the final block in 7-year-olds ($F(3,111)=4.158$, $p=.008$, $\eta^2_p=.100$) and in 9-year-olds ($F(3,72)=23.632$, $p<.001$, $\eta^2_p=.473$). The effects of Nameability in each age group were computed by ANOVA for the data aggregated across Training Block factor.

The performance of learning with high nameability locations for features did not significantly differ from that in the low nameability condition in 7-year-olds: $F(1,37)=3.43$, $p=.072$, $\eta^2_p=.085$. In 9-year-olds, however, performance was lower in the low nameability condition than in the high nameability condition: $F(1,24)=33.25$, $p<.001$, $\eta^2_p=.581$ (Table 3).

Discussion

We demonstrated that the nameability of locations of an object's parts can help in learning new categories, but this works only for participants older than 9 years. Children in the younger 7-year-old group successfully learn new categories well enough, but the difference in ease of naming the location does not influence them.

Also, we did not find a difference in the average efficiency of learning between children of the two age groups: the efficiency of learning in the elder group in the high nameability condition was significantly higher, but their efficiency in the low nameability condition was somewhat lower compared to the younger group. Overall, this pattern of results indicates age-related changes in category learning mechanisms: 9-year-olds and older children, like adults, rely on the verbalization of features when learning new categories, while younger children do not yet use this support.

What is the possible explanation? In a study on learning categories based on the color of signs, Zettersten and Lupyan (2018) explain the influence of speech by the fact that names help participants to quickly find features of an object, distinguishing them from other features, as well as helping to memorize the results of a hypothesis test. The tasks which we used were not difficult and could be solved without additional verbalization. With primary school children, we may also identify another reason.

Young children are just starting to form categories with one relevant feature because it is difficult for them to focus on a possible feature that can fall under the categorization rule. In this case, language and verbalization can be a means for doing this. For adults, overt naming is no longer necessary, and therefore the mechanisms of language effects on category learning possibly differ in adults and children.

This hypothesis can be tested in future experiments. We can create a training procedure of using the names of parts (or locations) for a preliminary description of objects before forming a category. As experiments show (Miles, Brashears, Hatherley, & Minda, 2018, preprint), this helps to form new categories in adults. Creating new strategies at an earlier age may prove the importance of speech in the development of category learning abilities in children.

Conclusion

The present study has shown that nameability for the location of an object's parts can help in learning new categories, but only starting from the age of 9 years. Our experiment is only the first step of an integrated view of nameability and concept learning in children. Recent studies (Kotov, 2018; Zettersten & Lupyan, 2018) have shown that, in adults, an object part's nameability could serve as the basis for testing a hypothesis about a new categorization rule. We think the present results are compatible with these studies, and we plan to extend them in this direction to provide a comprehensive account from concept learning to concept and semantic memory development.

References

Choi, S., McDonough, L., Bowerman, M., & Mandler, J. M. (1999). Early sensitivity to language-specific spatial categories in English and Korean. *Cognitive Development, 14(*2), 241–268. doi:10.1016/s0885-2014(99)00004-0

Kotov, A. A. (2018). The impact of object part nameability on learning categories with statistically different rules. *The Russian Journal of Cognitive Science, 5(*2), 35–44. Retrieved from http://cogjournal.org/5/2/pdf/KotovRJCS2018.pdf.

Kotov, A., & Kotova, T. (2018). The role of different types of labels in learning statistically dense and statistically sparse categories. *The Russian Journal of Cognitive Science, 5(*3), 56–67. Retrieved from http://cogjournal.org/5/3/pdf/KotovKotovaRJCS2018.pdf

Levinson, S. C., Kita, S., Haun, D. B. M., & Rasch, B. H. (2002). Returning the tables: Language affects spatial reasoning. *Cognition, 84(*2), 155–188. doi:10.1016/s0010-0277(02)00045-8

Miles, S. J., Brashears, B. N., Hatherley, J., & Minda, J. P. (2018). Prior verbal description of novel stimuli improves the learning of information integration categories but not rule-described categories. *Psyarxiv,* doi:10.31234/osf.io/mnefc

Minda, J. P., Desroches, A. S., & Church, B. A. (2008). Learning rule-described and non-rule-described categories: A comparison of children and adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34(*6), 1518–1533. doi:10.1037/a0013355

Peirce, J. W. (2008). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics, 2*, 10: 1–8. doi:10.3389/neuro.11.010.2008

Waxman, S. R., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology, 29(*3), 257–302. doi:10.1006/cogp.1995.1016

Welder, A. N., & Graham, S. A. (2001). The influence of shape similarity and shared labels on infants' inductive inferences about nonobvious object properties. *Child Development, 72(*6), 1653–1673. doi:10.1111/1467-8624.00371

Westermann, G., & Mareschal, D. (2014). From perceptual to language-mediated categorization. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369(*1634), 1–10. doi:10.1098/rstb.2012.0391

Zettersten, M., & Lupyan, G. (2018). Using language to discover categories: More nameable features improve category learning. In *Proceedings of the 12th International Conference on the Evolution of Language (Evolang12)* Toruń, Poland: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika. doi:10.12775/3991-1.136

Appendix. Instruction for Category Learning Task (Translated from Russian)

"Now we are going to play a game. Imagine you have landed on a new planet. During the game, you will need to learn to distinguish two types of aliens by the location of the signs. There are two groups of aliens living there — Gazuns and Blickets. They look different and wear different clothes. They can be often found together on the same island where they usually have holidays. They do not need their clothes there. There are alien type signs on the skin on the aliens' feet. You should learn to distinguish between the two groups of aliens by these signs on their feet. There are two signs on the foot — one of them is important, the other one is not. The important sign is located in a specific place on the foot. The unimportant one is located in another place, however, this place is not relevant, so it does not provide any useful information. Thus, you should learn which place is important for each type of alien. Now you will be shown images of the feet of the two types of aliens. You will see two signs on each foot. Try to choose one of two places on the foot and decide which alien group foot this is. Press the LEFT button if you think that it is a Gazun, or the RIGHT button if you think that it is a Blicket. Immediately after your reply, you will be informed whether your answer is correct or not."

Легкость наименования локаций и категориальное научение у детей

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Аннотация. Какова связь между лексиконом человека и процессом познания? Многочисленные исследования показывают, что названия объектов ускоряют категориальное научение. В нашем предыдущем исследовании мы показали, что наличие названий для местоположения признаков объекта тоже помогает научению новым правилам категоризации. В настоящем эксперименте мы оценили выраженность данного эффекта в онтогенезе, сравнив формирование новых понятий у детей 7 и 9 лет. Испытуемые учились различать два вида инопланетян по знакам на их ноге. Мы варьировали местоположения знаков на силуэтном изображении ноги. В условии с высокой называемостью местоположения знаки располагались на тех частях ноги, для которых есть общепринятые названия (например, «пятка»). В условии с низкой называемостью — на тех, для которых используются редкоупотребляемые названия (например, «ахилл»). Формируемое правило требовало нахождения связи места знака и его изображения. В результате мы обнаружили, что только девятилетние испытуемые успешнее формировали понятие в условии с высокой называемостью местоположения, чем с низкой. Испытуемые в возрасте семи лет, несмотря на такое же успешное научение, не различались относительно легкости называния местоположений. Данные результаты обсуждаются в связи с развитием способности к формированию лексических категорий в ходе онтогенеза.

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Ключевые слова: категориальное научение, категория, правило категоризации, название, легкость наименования, название пространственных отношений

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Литература

Котов А. А. Влияние легкости называния признаков объекта на научение новым категориям // Российский журнал когнитивной науки. 2018. Т. 5. № 2. С. 35–44. URL: http://cogjournal.org/5/2/pdf/KotovRJCS2018.pdf

Choi S., McDonough L., Bowerman M., Mandler J. M. Early sensitivity to language-specific spatial categories in English and Korean // Cognitive Development. 1999. Vol. 14. No. 2. P. 241–268. doi:10.1016/s0885-2014(99)00004-0

Kotov A., Kotova T. The role of different types of labels in learning statistically dense and statistically sparse categories // The Russian Journal of Cognitive Science. 2018. Vol. 5. No. 3. P. 56–67. URL: http://cogjournal.org/5/3/pdf/KotovKotovaRJCS2018.pdf

Levinson S. C., Kita S., Haun D. B. M., Rasch B. H. Returning the tables: Language affects spatial reasoning // Cognition. 2002. Vol. 84. No. 2. P. 155–188. doi:10.1016/s0010-0277(02)00045-8

Miles S. J., Brashears B. N., Hatherley J., Minda J. P. Prior verbal description of novel stimuli improves the learning of information integration categories but not rule-described categories // Psyarxiv. 2018. doi:10.31234/osf.io/mnefc

Minda J. P., Desroches A. S., Church B. A. Learning rule-described and non-rule-described categories: A comparison of children and adults // Journal of Experimental Psychology: Learning, Memory, and Cognition. 2008. Vol. 34. No. 6. P. 1518–1533. doi:10.1037/a0013355

Peirce J. W. Generating stimuli for neuroscience using PsychoPy // Frontiers in Neuroinformatics. 2008. Vol. 2. P. 10: 1–8. doi:10.3389/neuro.11.010.2008

Waxman S. R., Markow D. B. Words as invitations to form categories: Evidence from 12- to 13-month-old infants // Cognitive Psychology. 1995. Vol. 29. No. 3. P. 257–302. doi:10.1006/cogp.1995.1016

Welder A. N., Graham S. A. The influence of shape similarity and shared labels on infants' inductive inferences about nonobvious object properties // Child Development. 2001. Vol. 72. No. 6. P. 1653–1673. doi:10.1111/1467-8624.00371

Westermann G., Mareschal D. From perceptual to language-mediated categorization // Philosophical Transactions of the Royal Society B: Biological Sciences. 2014. Vol. 369. No. 1634. P. 1–10. doi:10.1098/rstb.2012.0391

Zettersten M., Lupyan G. Using language to discover categories: More nameable features improve category learning // Proceedings of the 12th International Conference on the Evolution of Language (Evolang 12). Toruń, Poland: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2018. doi:10.12775/3991-1.136