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Short report

The role of the structure of parts and of the overall object shape in children's generalization of novel object names

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Abstract

We investigated the role of the structure of stimuli and their functional affordance on novel name generalization. Three- and 5-year-old children and adults were shown a training object with two possible functions, each one associated with a different part. They were taught about the name and the function of the object. We compared the classifications obtained for transfer stimuli composed of one part of the training stimulus—functional or not, perceptually transformed or not, or composed of all the original training parts. Even young children generalized the novel name to functional one-part transfer objects and disregarded non-functional or dysfunctional objects, although their generalizations were more constrained by perceptual similarity than that of the adults.

Keywords: Lexical development; Novel name generalization; Children; Function; Shape

A central question in recent studies on early word learning, is the degree to which learning novel words for artifacts is guided by (a) knowledge about function or (b) the activation of perceptual associations. A number of authors have argued and shown that young children's generalizations of novel names are determined by "superficial" perceptual properties, such as objects shape (e.g., Gentner, 1978; Landau, Smith, & Jones, 1988; Smith, Jones, & Landau, 1996: see also Graham, Williams, & Huber, 1999; Merriman, Scott, & Marazita, 1993). In contrast, other authors have maintained and shown that even 2–3-year-old children's namings can be driven by conceptually "deeper" properties such as objects function (Diesendruck, Markson, & Bloom, 2003; Kemler Nelson, 1999; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Kemler Nelson,

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Holt, & Chan Egan, 2004; Kemler Nelson & 11 Swarthmore College Students, 1995). In general, experimental manipulations that enhance function saliency also increase the probability of function-based generalizations (e.g., the plausibility of the function–appearance relation or the intentional character of the function of an object) (see Diesendruck, Hammer, & Catz, 2003, for a discussion).

These previous studies, however, did not manipulate the structure of transfer stimuli in order to understand what dimensions drive children's generalizations. In most studies, the experimenter compares stimuli which are perceptually similar to the training object but cannot perform its function with stimuli that are less similar to the training object but that can perform its function. In these experiments, the perceptual appearance of the functional and non-functional parts was not systematically manipulated. The shape of both the functional and the functionally irrelevant parts of the functional and dysfunctional test objects was transformed. In other cases, the functional part was not easy to identify (Gentner, 1978; Graham et al., 1999), or some parts of the training objects had no equivalent parts in the transfer objects (e.g., Merriman et al., 1993). In sum, the differences between studies, at the level of parts and of the overall shape of stimuli, result in an unclear picture regarding their respective role on novel name generalization.

Our purpose is to study whether young children would generalize a novel name associated with a standard object, the function of which is performed by one of its parts, to transfer stimuli composed uniquely of the functional part(s) of this object. In this context, it would be interesting to verify further if children generalize a novel name to perceptually transformed parts that can also perform the original function. This is a relevant question to study because the function of many articulated artifacts results from the action of specific parts rather than the action of an "overall object". It is also relevant because, in most studies, perception-based generalization has been explicitly conceived in terms of an overall perceptual similarity rather than similarity at the level of parts (e.g., Smith et al., 1996). Moreover, if children's novel name generalizations are based on object parts, does the perceptual similarity between the original functional part and the transformed functional parts matter in their generalization? Lastly, what influences on naming can be attributable to non-functional parts that contribute to the overall shape of an object?

We constructed one stimulus that could perform two functions, each one relying on a different part (Kemler Nelson et al., 1995). Depending on the function taught to the child, one perceptually salient part was functionally central, whereas the remaining salient part did not contribute to the demonstrated function. In Fig. 1, for the object displayed in the first cell (cell A), the ring was devised to calibrate balloons and the container to paint. The ring played no role for the "painting" function and the container was irrelevant for the "calibrate" function. In the case of function-based generalization, do children associate the novel name with the entire object or with the functional part only? In the latter case, they might generalize to objects composed of the original functional part only (cell C, Fig. 1). Moreover, will children generalize the novel name to an object composed of a perceptually transformed functional part (Fig. 1, cell D, for a perceptual transformation of the part, or E and F, for larger structural transformations)? In order to assess the role of the irrelevant parts contributing to the global shape, we also introduced stimuli composed of a perceptually transformed functional part, but which also contained the functionally irrelevant part of the standard object (Fig. 1, object G). If generalization is driven by the functional part only, the functional one-part objects (cell D, and, maybe, E and F) and the two-part objects (cell G) should be classified in the same way. We also introduced dysfunctional one-part objects (cells H and I) that were very similar to the original functional parts and might be incorrectly accepted by participants who would generalize on the basis of the shape of parts.

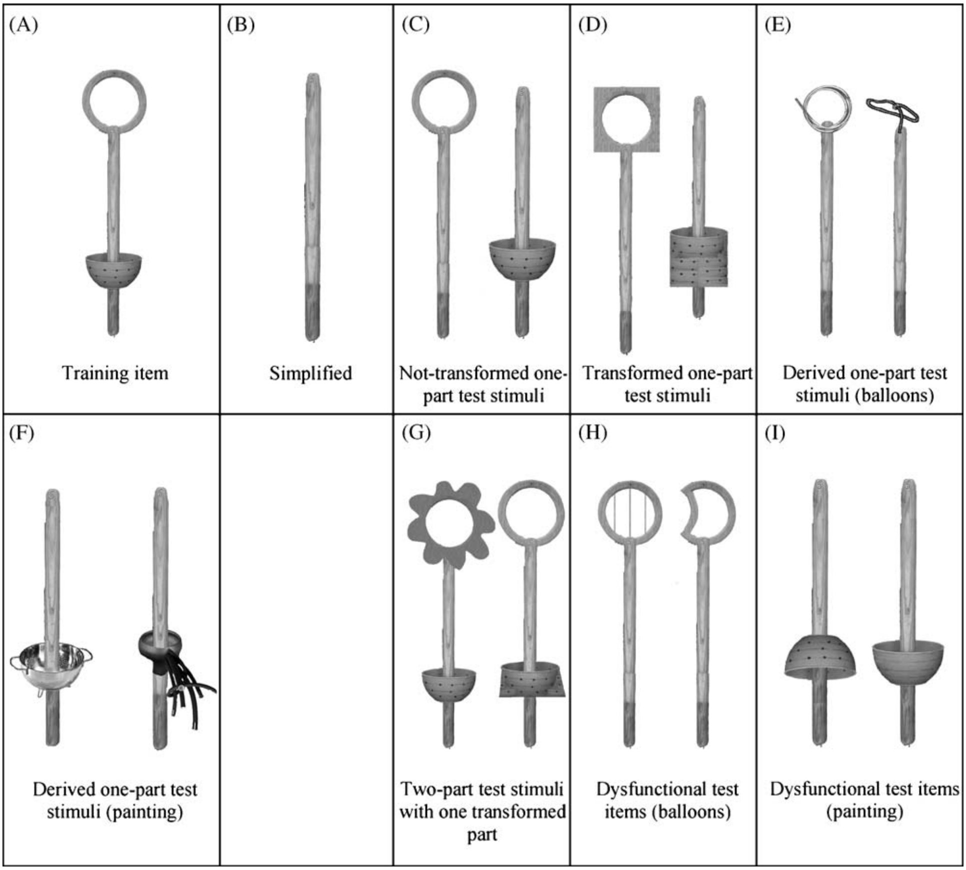

Fig. 1. Stimuli used in the experiment. Note that for one-part test items, being "functional" or "non-functional" depends on the theory that was taught to a participant. The dysfunctional items cannot perform the function of the corresponding original part and should always be rejected.

1. Method

1.1. Participants

Thirty children aged 3 years 0 months to 3 years 11 months (mean age = 3 years 5 months) and thirty children aged 5 years 0 months to 5 years 11 months (mean age = 5 years 5 months) participated in this experiment. Informed consent was obtained from their parents. Thirty undergraduate students also participated as volunteers in the novel name task. Participants were assigned randomly to one of the two functions, "balloons" versus "painting" (see below). Fourteen undergraduate students participated in the similarity rating task.

1.2. Materials

Two functions were assigned to the training object, calibrating inflatable balloons (the "balloons" theory) or "painting" (i.e., the "painting" theory). The training object was a real 3D object, made of wood and plastic. Test items were computerized transformations of a picture of this object. We used the 3D object in the training phase to make the function more understandable (see Kemler Nelson, 1999, for a discussion). The training object was referred to as "puk" (a non-word in French) and was composed of three parts: a pole, a ring, and a container with small holes (see Fig. 1). Each theory was illustrated by a sequence of pictures depicting the corresponding function.

The functional part in one condition, the ring in the "balloon" condition and the container in the "painting" condition, had no function in the other condition. Seven types of transfer stimuli were used to assess children's scope of generalization (Fig. 1). First, there was the training object (cell A). Second, we had the original pole (Simplified item, cell B). Third, there were functional and non-functional one-part test items composed of a part which was not transformed. The functional status of a one-part test item depended on the function that was taught. Particularly, "non-functional" means that the part had no role for the function which was taught (i.e., "painting" or "balloon") (cell C). Fourth, we had functional and non-functional *transformed* one-part *test items* that were composed of a part that was perceptually modified. However, the part could fulfill the function and its shape was perceptually reminiscent of the shape of the original part (cell D). Fifth, there were functional and non-functional *derived* one-part *test items* (cells E and F, for the "balloon" and the "painting" function, respectively); the original part was replaced by a *new* part that could fulfill the same function. Sixth, there were *two-part test items with one transformed part* consistent with both functions. The shape of one of the two parts, either the ring (cell G, left) or the container (cell G, right), was modified; the transformed part was either functional or non-functional, depending on the function that was taught. Seventh, we had *dysfunctional* one-part *test items*; they were perceptually very similar to one part of the training object but could not perform the corresponding function (cells H and I); the term "dysfunctional" was given by reference to the function of the corresponding training part.

1.3. Procedure

1.3.1. Adults' similarity ratings

A group of adults was asked to rate the similarity between each modified part and the corresponding original part. This was done in order to relate differences between the scores obtained in the generalization task for the different types of transfer stimuli with perceptual differences between the stimuli. Each transformed part was presented on a computer screen next to the equivalent original part. Participants were requested to assess the perceptual similarity between these parts on a 1 (low similarity) -to-7 (high similarity) scale. They were asked to ignore any functional information in their judgment.

1.3.2. Learning and test phases

First, the learning object was described.

> "I'm going to show you an object that you've never seen before. This object is called a Puk. The Puk is composed of a pole with a ring on the top and a pierced container on the bottom. I'm going to show you how to use this Puk".

Then, participants were taught one of the two functions of the learning object, either calibrating inflatable balloons or painting with an unusual device. Participants in the "balloon" theory were taught that the object was used to keep balloons that have the "good" size. While explaining the function on the corresponding sequence of images depicting this function, the experimenter also referred to the real 3D object to make the function clear.

> "The Puk is used to select balloons that are not too big. In order to choose balloons, you have to pick up a balloon and try to pass it through the ring. Balloons that are not too big will pass through the ring and balloons that are too big will not pass through the ring".

Instructions were adapted for the "painting" theory. After this, children were asked to explain the function, to check their understanding. Last, test items were randomly presented, one by one. Participants had to decide for each test item whether it was a "puk" or not.

2. Results

2.1. Similarity ratings

The ratings for the four following classes of stimuli were compared: (i) the *transformed* one-part *test items*; (ii) the *derived* one-part *test items*; (iii) the transformed part of the *two-part* test items; (iv) the *dysfunctional* one-part test items. For each participant, a mean similarity rating score was computed for each class of part. A one-way analysis of variance with type of part as a repeated measure revealed a significant effect, $F(3, 51) = 36.77$, $p < .001$. A posteriori analyses (Tukey HSD) revealed that the *dysfunctional* one-part test items were significantly more similar to the corresponding training part than the three other types of parts, and that the *derived* one-part test items were significantly less similar to the corresponding training part when compared to the other types of part ($p < .05$). The other comparisons gave no significant difference ($p > .05$).

2.2. Test phase stimuli

Two children aged 3 who failed to accept the Training test items and to reject the Simplified test item were removed from the analyses. It was thought that they did not understand the task. The two theories were not introduced as a factor in the analysis. Performance was expressed in terms of percentage of acceptances of functional items and rejections of non-functional or dysfunctional items (Table 1). Recall that the "functional" or "non-functional" status of one part depends on the theory that was taught. Note that if participants answer according to function, they should categorize all the types of test items defined in Table 1 correctly.

For each age group, the percentage of correct responses (see Table 1) for each type of transfer items was compared with chance (i.e., 50%) by a t test (see Table 1 for the t values). Alpha was set to .05 for all stimulus types.

2.3. One-part test items

A t test revealed that children aged three did not differ from chance for functional transformed one-part test items. They made more errors than predicted by chance for functional derived test items. For the functional not transformed one-part test items, they were marginally better than chance. For the non-functional items and the blocked one-part, t tests revealed a performance significantly above chance level. For the children aged five, t tests revealed a performance significantly better than predicted by chance for all types of one-part items, except the derived one-part

Table 1
Percentages of correct responses for each test item type and the t value for each percentage when it was compared with random choice (50%)

Type of transfer items	3-year-olds ($N=28$)	5-year-olds ($N=30$)	Adults ($N=30$)
Functional not-transformed one-part items (cell C)	68, $t\,(1,27)=1.98$, $p=.057$	87, $t\,(1,29)=5.81^{*}$	87, $t\,(1,29)=5.81^{*}$
Non-functional not-transformed one-part items (cell C)	82, $t\,(1,27)=4.36^{*}$	90, $t\,(1,29)=7.18^{*}$	100[a]
Functional transformed one-part items (cell D)	39, $t\,(1,27)=-1.14$	70, $t\,(1,29)=2.84^{*}$	87, $t\,(1,29)=5.81^{*}$
Non-functional transformed one-part items (cell D)	96, $t\,(1,27)=13^{*}$	97, $t\,(1,29)=14^{*}$	97, $t\,(1,29)=14^{*}$
Functional derived one-part items (cells E and F)	32, $t\,(1,27)=-2.4^{*}$	50, $t\,(1,29)=0$	70, $t\,(1,29)=2.84^{*}$
Non-functional derived one-part items (cells E and F)	93, $t\,(1,27)=10.12^{*}$	98, $t\,(1,29)=29^{*}$	98[a], $t\,(1,29)=29$
Two-part items with the functional part being transformed (cell G)	79, $t\,(1,27)=3.62^{*}$	90, $t\,(1,29)=7.18^{*}$	100[a]
Two-part items with the non-functional part being transformed (cell G)	86, $t\,(1,27)=5.3^{*}$	93, $t\,(1,29)=9.36^{*}$	97, $t\,(1,29)=14^{*}$
Dysfunctional one-part items (cells H and I)	79, $t\,(1,27)=4.57^{*}$	83, $t\,(1,29)=6.02^{*}$	92, $t\,(1,29)=12.04^{*}$
No-function dysfunctional one-part items (cells H and I)	93, $t\,(1,27)=12.73^{*}$	90, $t\,(1,29)=7.18^{*}$	100[a]

Note: The functional status, "non-functional" or "functional", of each type of part depends on the theory that was taught to a participant. The score for a category of "functional" one-part test stimuli was computed on the stimuli that could fulfill the function that was taught. The score for a category of "non-functional" one-part test stimuli was computed on the stimuli that could not fulfill the function that was taught. Thus, each one-part test stimulus shown in Fig. 1 can be "functional" or "non-functional", depending on the theory. "Dysfunctional one-part" refers to a part that could not perform the function of the original corresponding part. "No-function dysfunctional one-part" refers to a part that had no function in the context of the theory that was taught.

* Significant effect at $p < .05$.

[a] t values cannot be computed for perfect performance (100%).

items (see Table 1). Adults' performance was perfect or above chance for all types of stimuli (see Table 1).

2.4. *Two-part test items*

t tests revealed that the three age groups were significantly better than chance (Table 1).

2.5. *Dysfunctional one-part test items*

For both types of dysfunctional stimuli, t test revealed that percentages of correct responses differed from chance for the three groups (Table 1).

In sum, 3-year-olds accepted the functional not transformed one-part while they failed to accept functional transformed items, compared with older children and adults. They nevertheless correctly rejected the non-functional one-part test items. Children aged five did slightly better and accepted functional transformed one-part stimuli. Adults also accepted functional derived one-part test items. Interestingly, younger children accepted the two-part functional part transformed items, even though the transformed functional part was as similar to the original corresponding part as the transformed part of the one-part transformed items.

3. Discussion

We compared children's and adults' novel name generalizations as a function of the structure of the transfer stimuli. Our experiment was a first attempt to assess how the shape of object parts and the global shape contribute to novel name generalizations. Interestingly, 3-year-olds generalized the novel name to the functional one-part stimuli and rejected the non-functional one-part stimuli even though these two types of stimuli were as similar to the corresponding part of the training item. Thus, their function-based generalizations were based on parts of objects, not on the global structure of the stimuli. However, the scope of their generalizations was limited since they rejected functional transformed one-part stimuli. By contrast, 5-year-old children included perceptually transformed functional one-part stimuli in the original category. The three age groups rejected the items that did not fit with the theory they were exposed to in the learning phase. These results show a developmental trend in the generalization of novel words from one-part items very similar to the corresponding part in the training stimulus to one-part items very dissimilar to the equivalent training part.

As for the role of the global structure of the object, the 3-year-olds' score for the *two-part test items* that were transformed on the functional part – 79% of generalizations – shows that this age group was influenced by the overall structure of the stimuli and suggests that their results for the transformed functional one-part test items (39%) were not due to the transformation per se. Indeed, the similarity between the transformed functional one-part stimuli and the corresponding part on the learning item did not differ from the similarity between the equivalent transformed functional part on the two-part test items and the same part on the learning item.

Compared with previous studies showing function-based naming (Diesendruck, Hammer, et al., 2003; Kemler Nelson et al., 2000; Kemler Nelson et al., 1995), our study demonstrates that children can also rely on specific functional parts, independently of the overall structure. In these previous studies, the influence of perceptual similarity was often conceived as an overall, global similarity whereas we show that local and global similarities strongly interact.

We have also shown that the interaction between the level of parts and the level of the overall shape of objects is central to the understanding of children's novel name generalizations. We think that a number of previous results can be explained in terms of the extent to which a part or the overall structure of the learning phase stimulus can be recognized in the transfer items. At one end of a continuum defined in terms of similarity, we find the functional test objects used by Kemler Nelson and 11 Swarthmore College Students (1995) or our not-transformed one-part test items. For these items, it was easy to recognize the functional part of the learning object. These stimuli were correctly classified on the basis of function, even by young children. At the other end of the same continuum, we find the same-function/different-shape test objects used by Graham et al. (1999) or Merriman et al. (1993) which had *no* part in common with the standard item. These items (and our derived transfer items) were difficult even for 5-year-olds. In other words, in these previous studies, the relation between an object part and a function was not *transparent* for the children, and they did not use this relation to ground the association between the novel name that was taught and the object.

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