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PRESCHOOLERS' INDUCTIVE SELECTIVITY AS A FUNCTION OF IMPLICIT AND CONCEPTUAL LEARNING

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Since pre-school age, children rely on contextual information while generalizing information about new objects. It is still uncertain what underlies this inductive selectivity; whether it is associative learning, which depends on the numbers of features that an object has, or conceptual learning, which depends on the features' content. In the first experiment, we varied the contextual information and found that 4-5-year-olds rely more on contextual features of the object (shape and colour of the background), but not on spatial ones (location). In the second experiment we varied the combination of context features and showed that, given a lack of information about an object (shape only), children rely on contextual spatial features more than on the object's features. Moreover, they prefer not to rely on contextual information at all if the object's information was modified (same shape but different colour). Together, these results indicate the dependence of inductive selectivity on conceptual learning, not only associative learning.

Keywords: inductive selectivity, induction, associative learning, conceptual learning, preschoolers

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Many studies on modern cognitive psychology show that both children and adults learn a great deal of contextual information while forming new categories (Macario, 1991; Allen, & Brooks, 1991). This effect is known as conceptual flexibility, or inductive selectivity, i.e. the effect of memorizing additional information, which is not necessary for an ongoing generalization task. This selectivity can speed up the process of category learning. For example, when people learn how to distinguish edible mushrooms from poisonous ones, then apart from the shape of the mushroom, they also remember after a while which trees they are more likely to find an edible mushroom near, and –where they will find poisonous ones. Bearing this contextual information in mind can help people to search for new mushrooms, as contextual information is often recognized earlier and so can adjust our attention to the appearance of objects with certain characteristics.

The nature of the inductive selectivity effect is still an important topic of discussion. On the one hand, this selectivity may seem to contradict the principle of cognitive economy, which states that not all given information must be learned but only those which are important for categorization (Gluck, & Bower, 1988; Anderson, 1991; Nosofsky, Palmeri, & McKinley, 1994). However, further studies in this area concluded that the inductive selectivity effect actually satisfies the cognitive economy principle, as people apparently use this additional information in future, less convenient situations, and thus saving some effort in their future learning (Bott, Hoffman, & Murphy, 2007).

Firstly, the task factor one of the factors which initiate inductive selectivity. Adults show less inductive selectivity in a classification task than in an inference task (Yamauchi, & Markman, 1998; Hoffman, & Rehder, 2010). However, in our previous research we found out that the task factor itself is limited to the relevance of new information to the participant's cognitive schemas (Kotov, & Dagaev, 2013). Therefore, even when performing the classification task, which, as previously established, does not initiate inductive selectivity, participants will still remember contextual information if it is relevant to their knowledge about categorizing objects. At the same time, there are no data to prove that the influence of the material factor can be canceled by the task factor. Thus, the question, as to the ratio of different learning factors in the mechanisms of inductive selectivity, remains open.

It is known that revealing and memorizing the regular relations between features of objects and situations during learning can occur both explicitly, i.e. when one is aware of the categorization rule and can verbally describe the defining features, and implicitly by associations (Ashby, 1998). If, in the first case, the flexibility of learning is a result of conceptual learning, then, in the second case, this flexibility could be the result of training perceptual attention, or associative learning. Associative learning has some particular qualities; it does not involve speech, it is involuntary, and we all have it since birth. The differentiation between these two ways of learning allows us to ask the question: to what degree is conceptual learning and perceptual attention responsible for the conceptual flexibility effect? However, as Sloutsky and Fisher showed in their experiment with preschoolers, the mechanisms of perceptual attention are sufficient for the forming of new categories with additional contextual information (Sloutsky, & Fisher, 2008).

In that experiment, 5-year-old participants were shown two blocks of triads. During the first block, children were told to choose between two test objects (all objects were geometric shapes of circles and triangles) and select the one, which fitted the target object by shape (the first base for categorization). In the second block, the colour of the object was the base for categorization (participants had to choose the test object and match the target by its colour). All first block triads were shown in context 1, and all second block triads were shown in context 2. The context was set by the colour of the background (green/yellow) and the position of the triads on the screen (upper right/lower left corner of the screen). The test triads were ambiguous, i.e. both of the two relevant features (shape/colour) were available. However, only one context was shown in each trial (contexts varied between groups).

The authors found a stable relationship between the objects' features and the context. For example, participants preferred the categorization by shape significantly more often when the test ambiguous triad was shown in context 1. As the experiment revealed, the children made those decisions implicitly. These results support Sloutsky and Fisher’s theory, which states that the only way of acquiring new categorization rules and creating context-dependent generalizations for children below 6 years of age is associative learning. At the same time, they assume that in older children, the execution of this function can be performed by another kind of learning.

The role of conceptual learning in selectivity: methodological issues

Despite this, some critics have noticed that Sloutsky and Fisher’s results are limited, because they tested children only in one context and the subjects could make matches without noticing the context cue at all (Hayes & Lim, 2013). In our opinion, there are more important difficulties when interpreting Sloutsky and Fisher’s results. They used meaningless material and parts of context (location and color of background) did not change in different phases, such as during training or the test. These produced rather restricted conditions for conceptual flexibility.

We suggest that 5-year-olds can actually rely solely on the resources of attention, but only given a lack of previous knowledge or if they have difficulties in combining new information with some which is previously known. This exact situation actually appears in Sloutsky and Fisher's experiment (2008). First, due to the neutrality of the experimental material, the children cannot link it to the information they already have stored in their memory. Second, and much more importantly, the features of the context (the background colour and position of the triads on the screen) cannot be linked to the object categorization rule in any other way but by associations.

However, in reality, information about objects which both children and adults deal with, may facilitate the choice of the optimal system of learning. If the features of the categorized object correspond strongly with the context and functional relationships can be found between them, then conceptual learning will be more suitable. In the fore mentioned example about the search for mushrooms, the context contains both spatial (positions of contextual parts including the object categorized) and object features (features of other objects present in context). For example, the mushrooms which are found could be connected to the direction the person was moving towards (spatial feature) as well as to the tree under which the mushroom was found (object feature). In this example, the object’s feature will be more relevant for inductive selectivity than the spatial one, as it is the object’s feature that is functionally related to the context. Therefore, we can expect that although features are present simultaneously, only one of them will be remembered.

The following experiment should test the suggestion that only the context's features, functionally related to the objects, will be used in the effect of the inductive selectivity.

Experiment 1

Method

The participants in the two experiments received a task about inductive inference, which consisted of two stages. At the first stage, they were shown images of insects and they had to predict the direction of the insect's movement, such as where it would collect food and where it would put it after (Picture 1 above). Participants were expected to make these predictions based on the insects' appearance (the presence of a trunk or the presence of legs). To successfully accomplish the training task, the children must have remembered both features of the insects from both groups, as well as the contextual features; spatial - the direction of the movement (up or down) - and object - the part of the plant (flower or leaf). At the second stage, they were shown hybrid images of the insects, which contained features of both groups, including the trunk and the legs. The hybrid insects were shown already sitting on either the flower or the leaf, and participants had to decide where it would be returning. By pointing out the direction of the insect's returning movement, participants made a categorial decision and defined the group that they thought the insect belonged to. Since the object features such as trunks and legs were of no longer use, the children had to rely solely on the contextual information.

The structure of the contextual information, divided according to spatial and object features of the context, was systematically varied through different experimental conditions. Participants therefore had to choose which part of the contextual information was more reliable. A choice based on the context’s spatial features (top or bottom) would testify to the dependence of inductive selectivity on how associative learning works, because these features do not have a functional relationship to the insect's features. A choice based on the context’s object features (flower or leaf) will testify to the dependence of inductive selectivity on the conceptual mechanisms of learning, because there is a functional relationship between these features.

Participants

36 children from the age of 4 to 5.2 took part in the experiment. All participants were recruited from two municipal kindergartens in Moscow. 5 participants were excluded from the analysis due to mistakes in the protocol and a lack of data.

Material

The training phase consisted of 16 trials, which included an image of the target object (an insect), images of two houses of different shapes and images of a plant with the flower on the upper part of the stem (context 1), with the leaf on lower part (context 2). The insect had a trunk in 8 of the training trials and legs in the other 8 training trials. The test phase consisted of 4 trials. All test trials had a hybrid image of an insect with both a trunk and legs. The images of the plant were different in two experimental conditions for the testing part (see Figure 1).

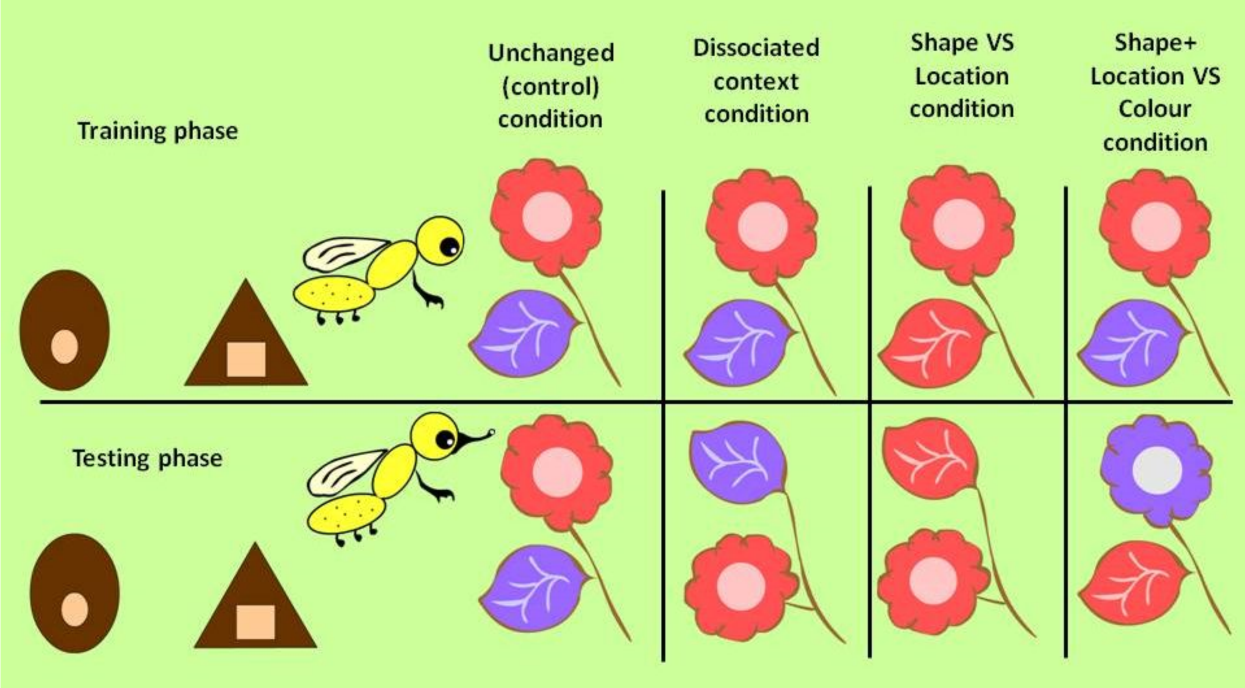

Fig. 1. Examples of training and testing stimuli used in Experiments 1 and 2.

In the control condition, the images of the plant on the testing part were the same as for the training part (red flower on top and blue leaf on the bottom). In the experimental condition for the testing phase, the parts of the plant were switched (red flower on the bottom and blue leaf on top).

Procedure

Subjects were randomly assigned to either the experimental condition or the control condition and carried out the training and the testing tasks. Participants were tested individually and all stimuli were presented to them on the screen of a laptop computer.

Training phase. Participants were invited to play a game with different and unusual insects. Before the game began, they were shown a scene with two houses on the left and a plant on the right. The experimenter showed them how an insect with a trunk flies out of the round house, sits on the flower and returns to the same house after a time. The experimenter told the participants that these insects (pointing to the image of the insect), which live in the round house, collect nectar and store it for the winter. Then the experimenter indicated the second insect with legs, flying out of the triangular house, landing on the leaf and returning to that same house after a time. While pointing to that insect, the experimenter said that the insects which live in the triangular house feed on leaves and store them for the winter. The experimenter did not tell them how the two groups of insects differed from each other in terms of their appearance. Right after the introduction, the training phase began.

The training phase consisted of 16 trials, grouped into 4 blocks of 4 trials each. In the first block, participants were shown an insect which was approaching the plant from the upper left corner of the screen and stopping in between the flower and the leaf. The experimenter then asked the participant where this insect would fly to next; either to collect nectar or to gnaw on the leaf. Depending on the participant's answer, the experimenter pressed one of two buttons and the insect flew to the place that the participant indicated. If the answer was correct, the insect returned to its home in two seconds. If the answer was incorrect, the insect stayed at the place and the experimenter told the participant that he or she had made a mistake and that those insects do not eat those kinds of things. The experimenter then pressed another button and the insect flew to the right spot and then returned to its house.

The first four training trials contained small images of insects near the image of the flower and the leaf. This was done because as discovered in the pilot series, 4-year-olds had difficulties in finding differences between two groups of insects without an example. If the experimenter did not name the relevant feature, then there was no opportunity to compare the insects from the same group simultaneously. Therefore, we asked children during those 4 training trials, which one of the two insect would receive help from the third insect, which had just arrived. The reduced images of insects were gone after those four trials. Overall, the participants went through 16 trials, grouped in 4 blocks. The insects from two groups were shown in a mixed order in the first and the last blocks (1-2-1-2 and 2-1-2-1). The second and the third blocks had the images of insects solely from one of the two groups (varied between blocks). The mixed blocks (1st and 4th) were used to draw participants' attention towards the differences between objects; the unmixed blocks were used to draw and increase the participants’ attention towards the context.

Testing phase. The testing phase began right after the training phase. The participants were shown the scene with images of houses on the left and the image of the plant on the right, just like in the training phase (see Figure 1). A hybrid insect with both a trunk and legs was sitting on the plant, either on the flower or on the leaf. The experimenter, while not emphasizing the insect’s appearance, asked the participant to decide which house this bug was going to fly to ("Look, who's here! What do you think, which house is he going to fly to? Where does he live?"). At the same time, we did not name the part of the plant that the bug was sitting on, so as to not draw attention to the object features of the context. When the participant's answer was received, the experimenter pressed the corresponding button and the insect moved to the house they had indicated. There was no feedback on this phase of the experiment. Overall, there were four testing objects and they were shown in the different parts of the plant in turn.

The experimental conditions differed in the location of the contextual objects in the testing phase. In the *dissociated context condition*, the leaf and the flower on the plant switched locations (the leaf was now in the flower's place on the top of the plant, and the flower was in the leaf's place at the bottom of the plant). In the control condition, the *unchanged context, the* leaf and the flower stayed in their locations.

Thus, based on the participant's answer about which house the hybrid insect was going to return to, we could work out which group he thought the insect belonged to. Since the participant could not solve this task based solely on the insect's appearance, he had to rely on the available information from the context. For example, participants saw in the training phase that if the insect landed on the upper part of the plant, i.e. on the flower, then it would return to the round house. In the *dissociated context condition* in the testing phase, they saw a hybrid insect sitting on the upper part of the plant, but this time it was the leaf instead of the flower. If participants answered that the bug would return to the round house, then we concluded that they were relying on the spatial features of the context, but not on the object features. If participants answered that the bug would return to the triangular house, we thought that they were relying on the object features of the context, because the insects from the leaf were the ones which flew to the triangular house in the training phase.

The *unchanged context condition* did not allow us to work out which contextual features - spatial or object - the participant relied on, because the location of the plant's parts remained the same. This condition was used to replicate Sloutsky and Fisher's (2008) effect on the meaningful material, so that both the task structure and the material of our experiment were different. Moreover, the control *unchanged context condition*, where both spatial and object features of the context maintained their previous correlation, allowed us to assess whether the degree of reliance on the dissociated context would be lower than on the unchanged context.

If the participant relied on either spatial or object features of the context in all four test trials in the experimental condition, then theirs answers were marked as spatial or object respectively. Since it was impossible to distinguish those two types of answers in the control condition, participants' answers were marked simply as whether or not they contained reliance on the context.

Additional measures. Since participants in the testing phase actually saw a new insect in the context that was changed in some conditions - and changed in different ways -, then performing the test tasks could change the knowledge that they received on the training phase. In this case, we would not be able to claim that we were assessing inductive selectivity. Therefore, just after doing the test, the participants were shown the images of four insects from the training phase (with either a trunk or legs), appearing in the center of the screen, one after another. There were no images of houses and the plant on the screen. We asked the participants what each insect collects - nectar or leaves. By processing answers to that question, we could tell how much doing the test changed their memory of the rule that they had learned during the training phase. We kept only those participants' data who gave all four correct answers, i.e. correctly classified all images, for further processing.

Experimental design. We used between-subject experimental design with dissociativity of the contextual information as an independent variable, and reliance on contextual features as a dependent variable.

Results and discussion

Although both experimental conditions had identical training phases, we had to be certain whether participants from both groups had learned the categorization rule equally. Therefore, we compared the performance of the categorization using two groups. The mean amount of correct answers from 16 trials in the *unchanged context condition* (M=15.42; SD=1.07) did not differ from the mean amount of correct answers in the *dissociated context condition* (M=15.30; SD=0.83), $t(36)=0.17$, $p=0.87$. The performance was very high in both groups, and so all participants learned the features, distinguishing two groups of insects, by the beginning of the testing phase. To what degree were children aware of those features, whilst still relying on them? We did not conduct any special awareness test, although we recorded their comments at the beginning of the testing phase, when they saw the hybrid bugs for the first time. It is important to bear in mind that we asked participants the question, "Which house is that insect going to fly to?". It is noteworthy that none of participants said that the insect had changed and none of the children refused to answer the question.

However, we did receive some indirect evidence which suggested that the children may have noticed the change in the insect's appearance. For example, there were children who sent the hybrid insect into the same house in all four testing trials. In that case, the answers were not varied by any context feature. We decided to code these answers as a separate type, called "the refusal to rely on any context features". Therefore, the participants' answers in the *dissociated context condition* could be of three types and answers in the *unchanged context condition* could be of two types only. Three participants' answers could not be classified into any answer type. For example, two participants from the *dissociated context condition* relied on the object feature of the context in three trials, and on the spatial feature in one trial. One participant from the *unchanged context condition* relied on the context in two trials and did not in the other two. We excluded those participants' data from further processing, despite their correct identification of the nonhybrid insect in the final control task.

Table 1 shows the distribution of answers that participants from different conditions gave. Since it is impossible to tell what the participant relied on in the control condition - the spatial or the object features of the context - we did not compare the two groups with each other. The control condition could give us only two types of answers - with or without reliance on the context – and so we compared the received distribution with the expected uniform distribution ($p=0.5$). In the *dissociated context condition*, where three types of answers were possible, we also compared the received distribution with the expected one ($p=0.33$).

Table 1. Types of answers received from the test in the dissociated context condition and the unchanged context condition (control)

	Reliance on context		**Refuse to rely on context (%)**	**Total (%)**
	Reliance on object features (%)	***Reliance on spatial features (%)***		
Dissociated context condition	*14 (70.6)*	*1 (5.8)*	*4 (23.6)*	*19 (100)*
Control condition	*16 (84.2)*		*3 (15.8)*	*19 (100)*

The distribution in both conditions differed from what had been expected. Most participants from the *unchanged context condition* relied on the context, $\chi^2(1)=8.90$, $p<0.01$. Therefore, we replicated the effect of inductive selectivity from Sloutsky and Fisher's experiment (2008) using the meaningful material, and with a different task structure. Indeed, as can be observed, when it is impossible to rely on the object's features, participants make their judgments based on the context.

As we expected, most participants from the *dissociated context condition* did rely on the object features of the context, $\chi^2(2)=14.63$, $p=0.001$. At the same time, answers from the "reliance on the spatial features of the context" type and answers from the "refuse to rely on the context" type altogether made up less than 30% of all answers. This meant that there were no less of them than there were of answers reliant on the context in the *unchanged context condition*. Therefore, preschoolers not only connect the features of (categorized) objects to the context, but also assign weights to contextual features. The conditions of changing contexts (and the context changes in reality much more often than it remains the same) do not eliminate the effect of conceptual flexibility or inductive selectivity, but instead reveal its conceptual or nonassociative character.

However, the last statement can be disputed, because the object features of the context in our experiment consisted of two parts (shape and colour) and the spatial features were actually only one feature - direction. Perhaps the children preferred to rely on the object features not because of their functional relationship to the categorized objects' features, but simply due to an associative rule, in which more features of the previous context remained in part of the scene

To test this hypothesis, we conducted a second experiment, including two experimental conditions (see Figure 1). We made the number of objects and spatial features of the context equal in one of those conditions, which allowed us to check if it was actually the object feature that took priority in the effect of inductive selectivity. The object features from the other condition were dissociated at the testing phase; the colour of the plant's parts was changed at the testing phase, but the location was not. We therefore had an opportunity to test the influence of the associative summation of the context features. We were able to track whether participants would rely on both contextual features in this case. Moreover, the change which occurred broke the link between the object features of the context, which had been formed at the training phase. This meant that the results in this condition could reveal the significance of the relationship between the object features for inductive selectivity.

Experiment 2

Participants

An additional group of 40 children aged 4.1-5.4 was used. All subjects were recruited from the same municipal kindergartens, as in the first experiment.

Material and procedure

The experiment was conducted individually with each child. The structure of the training and the testing phases was identical to Experiment 1, except for two differences. The *form vs. location condition* had an equal amount of object and spatial features in the context; both the flower and the leaf had the same beige colour in both the training and the testing phases. The *form + location vs. colour condition* had the object features of the context dissociated at the testing phase; the colour of the plant's parts was changed at the testing phase and the location was not, so that the children saw the plant with the red flower on top and blue leaf on the bottom at the training phase, and the plant with the blue flower on top and the red leaf on the bottom at the testing phase.

The experimental design was between-subject. There were three types of answers; two types indicating what participants relied on, and the third type denoting that kind of answer, when the participant was giving the same response in all test trials. After completing the test, participants received control questions about nonhybrid insects; "What do they collect?" The participants' data were kept for further processing only if they answered correctly on all control questions.

Results

First, we assessed the performance in the training task. We would expect the lower performance in the condition, where the colour of both parts of the plant was the same, because this plant looks less natural and also the difference between the two groups of insects is less emphasized in this context. Nevertheless, the mean amount of correct answers out of 16 trials in the *form vs. location* condition (M= 15.50; SD= 0.76) did not differ significantly from the mean amount of correct answers in the changing colour condition (M= 15.80; SD=0.41), t(38)=1.55 p=0.13. The performance over the two groups was still very high, which suggests that participants saw the relevant feature of the insect and linked it to the contextual features. We processed the data separately in each group, and compared the received distribution with the expected uniform distribution (0.33) (see Table 2).

Table 2. Types of answers received for the test in the Shape VS Location Condition and the Shape+Location VS Colour Condition

Shape VS Location Condition			
Reliance on shape (%)	**Reliance on location (%)**	**Refuse to rely on context (%)**	**Total (%)**
2 (10)	*9 (45)*	*9 (45)*	*20 (100)*
Shape+Location VS Colour Condition			
Reliance on shape and location (%)	**Reliance on colour (%)**	**Refuse to rely on context (%)**	**N (%)**
6 (35)	*1 (5)*	*12 (50)*	*20 (100)*

As can be seen from the table, the most answers in the *shape vs. location condition* were "refuse to rely in context" (45%) or "reliance on location" (45%). This distribution did not differ from the expected uniform distribution, $\chi^2(2)=4.90$, p=0.09. Most answers in the *shape+location vs. colour condition* were "refuse to rely in context" (50%), $\chi^2(2)=9.10$, p=0.01. These results contradict the hypothesis of associative mechanisms of the inductive selectivity. Participants do not choose parts of the context by the amount of contextual features remained the same as in the previous context. The results in the *shape+location vs. colour condition* are especially significant in this regard; participants preferred not to rely on the context at all, rather than rely on two contextual features when object features were dissociated. Note that one object feature (shape) was now in a different relationship to the other object feature (colour). Some participants from that group pointed out at the beginning of the testing phase that the flower was new. Some children even called it “poisonous”. It seems that even a small change of few object features leads to a change in the perception of an object; it is perceived as a new object with new features and a new history.

The results in the *shape vs. location condition* look somewhat surprising. We received the highest amount of results, indicating an associative mechanism of learning here. Evidently, only a minimum amount of object information forces children to rely on the object's location as the basis for inductive selectivity. At the same time, they practically do not rely on object features at all (10%) if object features were dissociated. Much more often, they demonstrate a refusal towards inductive selectivity. Thus, we cannot say that associative mechanisms of learning are an easier or more natural way of acquiring information at preschool age. Instead, we could maintain that they are only very rarely addressed, and that using them is never easy.

General Discussion

We replicated the effect of inductive selectivity as described in Sloutsky and Fisher's (2008) paper, but using more meaningful material. This choice of material allowed us to establish different types of contextual features; spatial and object. We showed that children rely on object features of the context, while making categorial decisions in ambiguous cases, if these features are salient enough (a combination of shape and colour). the context’s spatial features will only be used to solve the categorial task, if the object’s features are weak. Finally, the change in the relationship between object features leads to the disappearance of the inductive selectivity effect.

In conclusion, our results show that the object features of the context adjust the effect of the inductive selectivity during the process of categorial learning. Therefore, we cannot consider this to be only driven by associative mechanisms. Moreover, our experiment is the first to show the limitations of the inductive selectivity effect. The dissociation of the object information can lead to a shift of attention from any contextual information, even if prior learning was successful. These results are similar to the blocking effect, where information was not added to the rule once the rule had been learned, even if that information correlated with the rule (Wasserman and Berglan, 1998). However, it is not the case in our experiment. The radical refusal to rely on the context we observed was not a consequence of learning the rule, since it did not appear in all conditions, but only when the relationship between the object features of the context was broken.

We did not conduct any additional tests for children's awareness of their reliance on contextual information. The children in Sloutsky and Fisher experiment (2008) did not demonstrate this awareness, but participants in Hayes and Lim’s study (2013) did. The structure of our experiment reveals another, and we think, more important principle of learning and inductive selectivity. We created conditions where participants could not make a judgment about an object's category based on its appearance (a hybrid insect), and also had to encounter a change in the context's structure. Therefore, they had to look for new bases from which to make decisions and to analyze parts of the context. Thus, it seems more important to study the process of category learning, during which people not only form rules, but can also apply these rules in the future, in very different situations.

The following questions remain for further research. How do children decide that there is not enough information about an object and switch to a reliance on the contextual information? It is also very important to assess how much the ability to rely on spatial and object features of the context changes with age. We presume that older children will prefer the object information to the spatial one, despite the small amount of object information, which is not the case with 4-year-olds.

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