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The Influence of Modality and Causal Accessibility on Category Extensions in Modal Categorization of Biological Categories

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Abstract

Previous categorization research focused on factual categorization with the factual question whether an exemplar is a member of a category, neglecting epistemic modal categorization with the modal question whether an exemplar is possibly a member of a category. Two experiments investigated how modality and causal accessibility influence category extension in the modal categorization of biological categories. Experiment 1 compared modal with factual categorization and revealed a possibility priming effect: relative to factual categorization, modal categorization tended to prime participants to accept exceptional exemplars that lacked a question category's essential properties, indicating a broader category extension. Experiment 2 further examined the influence of causal accessibility on possibility orientation (strong versus weak epistemic possibility) of modal categorization, and revealed a possibility orientation effect: modal categorization was more likely to be based on strong epistemic possibilities with causal constraints in the causally accessible condition than in the causally inaccessible condition, resulting in fewer acceptances of exceptional exemplars and thus a narrower category extension. Both experiments showed that genes, as essential properties, dominated the modal categorization of a biological individual even when its other properties did not causally coordinate with its genes. These findings pose challenges to the main existing accounts of the modal status of natural kinds and shed light on a modal perspective in categorization research.

Keywords: modal categorization; epistemic possibility; strong epistemic possibility; weak epistemic possibility; causal accessibility

Categorization is the cognitive process by which people judge whether an exemplar belongs to a certain category. For example, when considering the animal sparrow, people can judge that it belongs to the category of birds based on its properties (such as feathers and the ability to fly). “Learning to classify the world into categories is fundamental to human cognition” (Minda, Roark, & Kalra, 2024, p. 536).

Categorization tasks can be divided according to different criteria. First, based on whether feedback is provided to participants, they can be divided into categorization with feedback (the experimenter informs participants whether their category judgments are correct) and categorization without feedback (Lewis, Aaron, & Gregory, 2007; Mack & Palmeri, 2015; Yamauchi & Markman, 2002). Second, categorization tasks can be divided into qualitative categorization (judging whether an exemplar belongs to a certain category) and quantitative categorization (judging the degree to which an exemplar belongs to a certain category) (Ahn et al., 2000; Rehder & Kim, 2006; Rehder & Hastie, 2001; Simons & Keil, 1995). Finally, according to the modality of categorization, we divide categorization tasks into factual categorization (judging whether an exemplar is a member of a category) and modal categorization (judging whether an exemplar is epistemically possibly a member of a category). Previous categorization research primarily examined factual categorization, neglecting modal categorization. The present study aims to explore modal categorization. We first review research on factual categorization and then examine modal categorization in detail.

Previous research on factual categorization has indicated that categorization is fundamentally based on comparing new exemplars with category representations (Minda et al., 2024; Rehder, 2010; Rehder & Kim, 2006; Lewis et al., 2007; Smith, Patalano, & Jonides, 1998). Depending on the way of comparison, categorization can be divided into similarity-based and knowledge-based categorization. These two types of categorizations assume different category representations.

Similarity-based categorization assumes that category representations are either prototypes (instances embodying typical features of the question category) or exemplars (multiple instances of the question category stored in brains), and categorization consists of comparing an exemplar with prototypes or stored exemplars in terms of similarity and judging whether the exemplar belongs to the question category based on the degree of similarity. The higher the degree of similarity, the more likely people are to judge the exemplar as a member of the question category. Knowledge-based categorization assumes that category representations consist of some forms of knowledge, and categorization consists of comparing an exemplar with these forms of knowledge in terms of how well they match and judging whether the exemplar belongs to the question category based on the degree of matching. The higher the degree of matching, the more likely people are to judge the exemplar as a member of the question category.

Knowledge-based categorization relies mainly on rules, on knowledge (psychological essentialism) of the essential properties of categories, and on knowledge of the causal relations among category properties. “Psychological essentialism is the hypothesis that humans represent some categories as having an underlying essence that unifies members of a category and is causally responsible for their typical attributes and behaviors” (Neufeld, 2022, p. 1). Psychological essentialism distinguishes between essential and non-essential properties of categories. In biological categories, people primarily judge whether an exemplar belongs to a category based on whether it possesses the category’s essential properties (Berent, 2021; Haukioja et al., 2023; Machery et al., 2023; Neufeld, 2022; Rips, 2001, 2011; Waxman et al., 2007). When an exemplar’s non-essential properties conflict with its essential properties, people are more likely to base category judgments on the essential properties (Keil, 1989; Simons & Keil, 1995). Previous research has shown that people generally consider properties such as appearance and living environment to be non-essential

properties of categories, while lineage, gene system, and internal anatomy are viewed as essential properties (Barton & Komatsu, 1989; Gelman & Wellman, 1991; Gelman, 2004; Martínez-Manrique, 2025; Rips, 2011; Simon & Keil, 1995). However, some studies have challenged psychological essentialism (Hampton et al., 2007; Haukioja et al., 2021; Machery et al., 2023). For example, regarding identity essentialism and causal essentialism, while people generally believe that certain superficial properties of a category are caused by their underlying essence, this essence may be a matter of degree and does not entirely determine an example's categorization. The current study is based on the assumption of psychological essentialism. As Dar-Nimrod and Heine (2011) put it, "Genes can explain almost everything" (p. 800), and "'genes' (or at least the way that most laypeople conceive of genes) often serves as the placeholder for this imagined essence" (p. 801). Furthermore, "many people may believe that genes, embodied in DNA, contain this essence for biological kinds and that this genetic essence differentiates the species" (Hampton et al., 2007, p. 1787). Therefore, we propose the genes-dominated categorization hypothesis: among the multiple essential properties of a biological category, the gene system (DNA) of a biological individual will dominate categorization even when its other properties do not causally coordinate with its genes.

Research on causality-based categorization shows that causal laws (causal relations among category properties) influence category judgments (Rehder & Hastie, 2001; Rehder, 2003; Rehder & Ross, 2001; Rehder & Kim, 2010). In a causal network, category properties that are upstream in the causal network or have more associated causal relations play greater roles in categorization (Ahn & Lassaline, 1995; Luhmann et al., 2006; Rehder & Hastie, 2001). Compared to exemplars that mismatch causal laws, those that match causal laws are more often judged to be members of the question categories (Rehder & Kim, 2006, 2010).

Although previous research has not examined modal categorization, Rips (2001, 2011) explored

the modal status of the properties of natural categories, that is, what properties the members of a natural kind *might* have or *must* have across (possibly counterfactual) circumstances. Rips (2011) proposed two views—the intrinsic view and the interaction view—to explain properties' modal status. The intrinsic view holds that "natural kinds depend for their existence on certain internal properties of instances that dictate their category membership and many of their other (internal and external) properties" (p. 228). It emphasizes the decisive role of essential properties in determining category membership. Some previous studies support this view. In transformation tasks, altering external properties (such as appearances) typically does not affect category membership, while changing essential properties (such as internal anatomy) does alter it (Barton & Komatsu, 1989; Prasada & Dillingham, 2006; Simons & Keil, 1995). For example, when judging "if a dog loses its internal anatomy (such as blood, bones, etc.) and has only its external structure left, is it still a dog?" participants tended to answer negatively. In contrast, when judging "if a dog loses its external structure (such as fur, skin, etc.) and only has its internal anatomy left, is it still a dog?" participants were more likely to answer affirmatively. Furthermore, in category-based inductive reasoning tasks, when people know that a member of a category possesses an essential property, they tend to infer that other members of the category also possess that property (Gelman & Markman, 1986; Mandler & McDonough, 1998). For example, Gelman & Markman (1986) showed participants images of a dinosaur (apatosaurus) and a rhinoceros, informing them that "This dinosaur (apatosaurus) has cold blood, and this rhinoceros has warm blood." When asked, "Does this dinosaur (Triceratops) have cold blood or warm blood?" participants were more likely to believe that Triceratops has cold blood.

The interaction view emphasizes that the membership of category members is determined by interactions among multiple causal factors. Some previous studies also support the interaction view.

Studies have shown that in transformation tasks, category membership is not solely based on essential properties but rather depends more on causal interactions among multiple properties within natural categories (Rosch, 1978; Rips, 2001, 2011). “If an object violates enough of these laws (whereas other members continue to instantiate them), then we should consider the object no longer a member of the kind in question” (Rips, 2011, p. 237). Studies have shown that in category-based inductive reasoning tasks, “individual members of interactional kinds have overlapping causal properties; hence, new properties that are bound up with the old ones will tend to carry over to other members of the same kind” (p. 233) (Rehder & Hastie, 2001; Rehder, 2006; Sloman, 1997).

In summary, Rips (2001, 2011) argues that essential properties and causal interactions affect modal characteristics of natural category properties, stating that “people are basing their responses not merely on what’s true of existing members of the category but on what’s possible for them” (Rips, 2011, p. 225). This relates to the range of variation of possible exemplars allowed by a category beyond its actual properties. However, in previous studies on modal characteristics, transformation tasks and category-based inductive reasoning tasks both employed factual questions that asked participants to make factual “yes/no” judgments, rather than modal questions (containing modal terms like possibly/may/must/cannot) that asked participants to make modal judgments. Strictly speaking, these factual questions, which lack modal terms, do not adequately reveal people’s modal understanding of category properties. To really examine modal status of category properties, modal terms should be introduced into task questions. Specifically, transformation tasks could ask participants whether a transformed exemplar is possibly an individual of the category. Participants’ responses to such questions would really reflect their modal understanding of category properties. We conducted two experiments that directly examined modal categorization, in which participants were asked to judge whether exemplars were possibly individuals of the question

category. The present two experiments aimed to examine whether essential properties of biological categories and causal laws of category properties would affect modal categorization.

Factual categorization requires people to judge whether an exemplar belongs to a category. In factual categorization, people are more often constrained by essential properties of the question category and are less likely to accept exceptional exemplars without essential properties. This leads to a smaller range of variation of exemplars allowed by the category. Modal categorization requires participants to judge whether an exemplar is possibly an individual of a category. Compared with factual questions, modal questions are expected to prime people to go beyond the constraints of the essential properties of the question category and to imagine that exceptional exemplars without these essential properties are possibly its individuals. This expands the range of variation of exemplars within the category and thus its extension. Therefore, we propose the possibility priming hypothesis that modality of categorization questions will affect categorization: compared to factual categorization, modal categorization will prime people to imagine exceptional exemplars without essential properties and so yield more acceptances of exceptional exemplars, indicating a broader category extension.

The type of modality under investigation. Modality comes in several forms. Epistemic modality concerns what is possible relative to a reasoner's knowledge or evidence; nomological modality concerns what is compatible with the laws of nature; deontic modality concerns what is permitted or obligatory; and metaphysical modality concerns what is possible given the nature of things (Egan & Weatherson, 2011; Kment, 2012). Because the bare word "possibly" does not by itself distinguish among these forms, the intended sense must be fixed by the task at hand. The present study targets epistemic (cognitive) possibility: whether, given the knowledge participants can bring to bear, an exemplar could be a member of a category.

For modal categorization, we adopt the distinction between strong and weak epistemic possibility (Egan & Weatherson, 2011; Kment, 2012; Przyjemski, 2017). Strong epistemic possibility (SEP) refers to the potential for something to occur based on some specific real conditions that enable it to occur, that is, "A proposition *p* is strongly epistemically possible just in case *p* is supported by (non-overridden) evidence" (Przyjemski, 2017, p. 190). Weak epistemic possibility (WEP) refers to what is logically compatible (without contradiction) with known premises. This possibility is not constrained by real-world conditions and can lack support from those conditions, that is, "A proposition *p* is weakly epistemically possible just in case *p* is compatible with the relevant body of evidence" (Przyjemski, 2017, p. 190). For example, can a child become an astronaut in the future? From the perspective of SEP, becoming an astronaut requires passing a stringent selection procedure, including medical examinations, psychological evaluations, and assessments of professional skills. Therefore, constrained by these real conditions, ordinary people are more likely to believe that it is impossible for him or her to become an astronaut in the future. However, from the perspective of WEP, becoming an astronaut is logically compatible with the premise "he is a person". Hence, ordinary people should consider it possible for him or her to become an astronaut in the future. In summary, possibility in this context can be understood as either SEP or WEP. We for the first time apply this distinction to modal categorization.

SEP is applicable to modal categorization that is based on causal relations among category properties. These causal relations serve as realistic constraints in categorization. Previous research on factual categorization has indicated that when these causal relations are present, exemplars that match causal laws of the question category are judged more often as members of that category compared to those that mismatch (Rehder & Hastie, 2001; Rehder & Kim, 2006; Rehder & Kim, 2010). Furthermore, Rips (2001, 2011) suggests that exemplars violating multiple causal laws

within a category are judged less frequently as members of the category. Similarly, when causal relations among category properties are present in modal categorization, category judgments should likewise be affected by this realistic constraint.

WEP is applicable to modal categorization that is based on the essential properties of categories. Previous research on factual categorization has shown that in the absence of causal relations between essential and non-essential properties, exemplars with essential properties of the question category are more often judged as members of that category compared to those that do not (Simons & Keil, 1995; Berent, 2021; Neufeld, 2022; Rips, 2001, 2011). Similarly, essential properties will dominate modal categorization based on WEP. However, as the possibility priming hypothesis suggests, compared to factual categorization, in modal categorization possibility questions will make people less affected by essential properties of a category because, for category exemplars, WEP may suggest that exemplars without the essential properties are also possible.

The two interpretations of possibility in modal categorization imply that causal accessibility (the presence versus the absence of causal relations among category properties) will affect possibility orientation of modal categorization. Therefore, we propose the possibility orientation hypothesis: in the absence of causal relations among category properties, people will tend to base their category judgments on WEPs without causal constraints, and so people will be more likely to accept exceptional exemplars without essential properties as possible; whereas in the presence of causal relations among category properties, people will tend to base their category judgments on SEPs with causal constraints, and so people will be less likely to accept exceptional exemplars as possible. Overall, modal categorizations are more likely to be based on SEPs with causal constraints in the causally accessible condition than in the causally inaccessible condition, and so the extension of a category will be narrower in the causally accessible condition than in the causally inaccessible

condition.

In summary, the present two experiments aimed to test the above hypotheses about category extensions. Experiment 1 would compare factual and modal categorization to test the possibility priming hypothesis and the genes-dominated categorization hypothesis. Experiment 2 would further examine whether causal accessibility would affect possibility orientation (WEP versus SEP) of modal categorization.

Experiment 1

Method

Participants. The aim of this experiment was to examine whether modal categorization would allow a greater range of variation of category exemplars than factual categorization. We conducted a priori power analysis using the "χ^2 tests" in G*Power 3.1. By setting the medium effect size W = 0.3, and according to statistical requirements (α = .05, *power* = 1 - β = .80), we calculated that a total of at least 88 participants were needed for the two experimental conditions. To ensure statistical power, we recruited 120 college students (33 males and 87 females) from XXX university. They had not taken any logic courses. They were randomly arranged into two groups, with 60 participants in each group.

This research received ethical approval from the XXX University Human Research Ethics Committee. All participants provided informed consent to participate.

Design and Materials. Experiment 1 used a single-factor (questioning way of categorization: factual questions vs. modal questions) between-group design. The dependent variable was participants' category judgments. Each questioning way corresponded to a categorization task questionnaire. To ensure the replicability of results, in each task there were two opposing biological

categories: weasels and squirrels. These two categories exhibited binary, opposing properties on each of four dimensions (appearance, internal anatomy, gene system, and lineage). The combination of these four dimensions formed 2 × 2 × 2 × 2 = 16 imagined animal individuals. In the modal categorization questionnaire, the 16 animal individuals were presented in a list format in Table 2. For each animal individual, participants were asked to judge whether it is possibly a weasel and whether it is possibly a squirrel. Participants were required to complete a total of 32 category judgments.

We encoded the features of each animal individual in Table 2. On the same dimension, weasel properties were represented by 1, while squirrel properties were represented by 0. The 16 imagined animal individuals were encoded as follows: 1-1111, 2-0111, 3-1110, 4-1011, 5-1101, 6-0110, 7-0011, 8-0101, 9-1010, 10-1100, 11-1001, 12-0010, 13-0100, 14-0001, 15-1000, 16-0000. For each animal individual, the five-digit codes respectively represent its identification number, appearance, internal anatomy, genes, and lineage.

The degree of similarity between each animal individual and the question category was indicated by how many of the four properties of the category prototype the individual possesses. For the 16 animal individuals, there were five levels of similarity: 4/4 (typical exemplars), 3/4 (untypical exemplars), 2/4 (marginal exemplars), 1/4, and 0/4. Levels of similarity determined whether exemplars were typical, untypical or marginal for the category. For the weasel category, its typical exemplar corresponding to its prototype was 1-1111, its untypical exemplars were 2-0111, 3-1110, 4-1011, and 5-1101, and its marginal exemplars were 6-0110, 7-0011, 8-0101, 9-1010, 10-1100, and 11-1001. For the squirrel category, its typical exemplar was 16-0000, its untypical exemplars were 12-0010, 13-0100, 14-0001, and 15-1000, and its marginal exemplars were 6-0110, 7-0011, 8-0101, 9-1010, 10-1100, and 11-1001.

We used acceptance rates of exceptional exemplars without the question category's genes (the fundamental property hypothesized in this study) to indicate the range of variation of exemplars allowed by the question category. Among exceptional exemplars (without weasel genes) of weasels, marginal exemplars (8-0101, 10-1100, 11-1001) and the untypical exemplars of squirrels (13-0100, 14-0001, and 15-1000) were extreme exemplars of weasels in that these exemplars showed lower similarity (≤ 2/4) to weasels. Judging these exemplars as weasels cannot be explained by similarity or psychological essentialism, so the proportion of judging these exemplars as weasels would reflect the range of variation of exemplars allowed by weasels. Conversely, for exemplar 5-1101 (without weasel genes, but with 3/4 similarity to weasels), judging it as a weasel can be explained by similarity, as indicating that this exemplar could not reflect the range of variation of exemplars allowed by weasels. Similarly, in squirrels' exceptional exemplars, marginal exemplars (6-0110, 7-0011, 9-1010) and untypical exemplars of weasels (2-0111, 3-1110, 4-1011) were extreme exemplars of squirrels showing lower similarity to squirrels (≤ 2/4). Exemplar 12-0010 (without squirrel genes, but with 3/4 similarity to squirrels) was not an extreme exemplar of squirrels. In summary, both weasels and squirrels had six extreme exemplars each.

In the modal categorization questionnaire, the presentation order of the 16 exemplars was counterbalanced. One presentation order was shown in questionnaire (A1), while the reverse of this order constituted questionnaire (A2). Similarly, the factual categorization questionnaire included two versions with the counterbalanced orders, B1 and B2. We present the English version of the Chinese modal categorization questionnaire A1 below. The factual categorization questionnaire was adapted from the modal categorization questionnaire by removing the word "possibly" from the modal questions in the latter

The modal categorization questionnaire A1

Instructions

Welcome to this experiment. Please read the following task carefully and complete the items in order.

The following pictures present two mammal species; weasels and squirrels. Table 1 lists the properties of these two kinds of animals. Table 2 shows the property combinations of some imaginary animal individuals. According to the information provided, please judge whether each imaginary animal in Table 2 is possibly a weasel or a squirrel. In the last two columns of Table 2, place a check mark (√) in one of options "Yes" and "No" to indicate your judgement.





Table 1 *Properties of weasels and squirrels*

Features	Weasels	Squirrels
Appearance	Slender, elongated bodies with yellow fur. Long snouts, no ear tufts, big and bright eyes. Short limbs, and long, thin tails.	Small, round bodies with black and reddish-brown fur. Short snouts, with ear tufts. long limbs, and thick, bushy tails.
Internal anatomy	With weasels' internal anatomy.	With squirrels' internal anatomy.
Gene system	With weasels' DNA.	With squirrels' DNA.
Lineage	Offspring are produced viviparously through mating between male and female weasels.	Offspring are produced viviparously through mating between male and female squirrels.

Table 2 Please judge whether each imaginary individual is possibly a weasel or a squirrel.

Imaginary animal individuals	Appearance	Internal anatomy	Gene system	Lineage	Is this animal possibly a weasel?	Is this animal possibly a squirrel?
Animal 1	Appearance of weasels	Internal anatomy of weasels	DNA of weasels	Lineage of weasels	Yes No	Yes No
Animal 2	Appearance of squirrels	Internal anatomy of weasels	DNA of weasels	Lineage of weasels	Yes No	Yes No
Animal 3	Appearance of weasels	Internal anatomy of weasels	DNA of weasels	Lineage of squirrels	Yes No	Yes No
Animal 4	Appearance of weasels	Internal anatomy of squirrels	DNA of weasels	Lineage of weasels	Yes No	Yes No
Animal 5	Appearance of weasels	Internal anatomy of weasels	DNA of squirrels	Lineage of weasels	Yes No	Yes No
Animal 6	Appearance of squirrels	Internal anatomy of weasels	DNA of weasels	Lineage of squirrels	Yes No	Yes No
Animal 7	Appearance of squirrels	Internal anatomy of squirrels	DNA of weasels	Lineage of weasels	Yes No	Yes No
Animal 8	Appearance of squirrels	Internal anatomy of weasels	DNA of squirrels	Lineage of weasels	Yes No	Yes No
Animal 9	Appearance of weasels	Internal anatomy of squirrels	DNA of weasels	Lineage of squirrels	Yes No	Yes No
Animal 10	Appearance of weasels	Internal anatomy of weasels	DNA of squirrels	Lineage of squirrels	Yes No	Yes No
Animal 11	Appearance of weasels	Internal anatomy of squirrels	DNA of squirrels	Lineage of weasels	Yes No	Yes No
Animal 12	Appearance of squirrels	Internal anatomy of squirrels	DNA of weasels	Lineage of squirrels	Yes No	Yes No
Animal 13	Appearance of squirrels	Internal anatomy of weasels	DNA of squirrels	Lineage of squirrels	Yes No	Yes No

Animal 14	Appearance of squirrels	Internal anatomy of squirrels	DNA of squirrels	Lineage of weasels	Yes No	Yes No
Animal 15	Appearance of weasels	Internal anatomy of squirrels	DNA of squirrels	Lineage of squirrels	Yes No	Yes No
Animal 16	Appearance of squirrels	Internal anatomy of squirrels	DNA of squirrels	Lineage of squirrels	Yes No	Yes No

Hypothetical predictions. Neither psychological essentialism nor similarity-based categorization was formulated for modal questions, so neither makes a direct prediction about whether factual and modal categorization would differ. The possibility priming hypothesis supplies the following prediction: participants would more often accept exceptional exemplars without the question category's genes in modal categorization than in factual categorization. Moreover, it was expected that both factual and modal categorization would follow the genes-dominated categorization hypothesis.

Procedure. Participants completed the test voluntarily in a classroom. The questionnaires corresponding to the two conditions were distributed to participants in the order of A1B1A2B2, ensuring a balanced allocation of participants across the four questionnaires. There was no time limit for completing the questionnaires, and participants took about 15 minutes to do so.

The datasets of the present experiments are available at the link mentioned in the cover letter.

Results

The results of category judgments are shown in Table 3.

In both factual and modal categorization, most participants tended to categorize the exemplars with weasel genes as weasels. Similarly, most participants tended to categorize the exemplars with squirrel genes as squirrels. Even when an exemplar's genes did not coordinate with its other properties (for example, exemplars 5-1101 and 12-0010), participants still tended to categorize the

exemplar based on its genes (more participants categorized 5-1101 as a squirrel and 12-0010 as a weasel). This indicated that categorization was primarily based on genes. This result supported the genes-dominated categorization hypothesis.

Table 3 *Acceptance frequencies (rates) of 16 exemplars in question categories in Experiment 1*

Exemplars	Factual categorization		Modal categorization	
	Weasels	Squirrels	Weasels	Squirrels
1-1111	56 (93.3%)	2 (3.3%)	58 (96.7%)	2 (3.3%)
2-0111	50 (83.3%)	6 (10.0%)	51 (85.0%)	9 (15.0%)
3-1110	50 (83.3%)	5 (8.3%)	45 (75.0%)	22 (36.7%)
4-1011	46 (76.7%)	6 (10.0%)	52 (86.7%)	20 (33.3%)
5-1101	8 (13.3%)	39 (65.0%)	28 (46.7%)	40 (66.7%)
6-0110	51 (85.0%)	5 (8.3%)	49 (81.7%)	22 (36.7%)
7-0011	45 (75.0%)	7 (11.7%)	50 (83.3%)	24 (40.0%)
8-0101	13 (21.7%)	45 (75.0%)	28 (46.7%)	41 (68.3%)
9-1010	43 (71.7%)	14 (23.3%)	45 (75.0%)	33 (55.0%)
10-1100	8 (13.3%)	48 (80.0%)	21 (35.0%)	52 (86.7%)
11-1001	8 (13.3%)	48 (80.0%)	23 (38.3%)	48 (80.0%)
12-0010	32 (53.3%)	22 (36.7%)	42 (70.0%)	30 (50.0%)
13-0100	1 (1.7%)	54 (90.0%)	16 (26.7%)	50 (83.3%)
14-0001	8 (13.3%)	51 (85.0%)	26 (43.3%)	49 (81.7%)
15-1000	4 (6.7%)	54 (90.0%)	6 (10.0%)	57 (95.0%)
16-0000	1 (1.7%)	59 (98.3%)	3 (5.0%)	59 (98.3%)

***Note*.** For each condition, $N = 60$. For each individual' codes, 1 indicates properties of weasels, while 0 indicates properties of squirrels. From left to right, the four properties of each individual correspond to the dimensions of appearance, internal anatomy, gene system, and lineage, respectively.

Moreover, we compared the acceptance rates of exemplars 5-1101 and 12-0010 to investigate whether categorization was based on similarity, genes, or lineage. When the question category was weasels, in terms of similarity, the similarity (3/4) of 5-1101 to weasels was greater than that (1/4)

of 12-0010 to weasels. In terms of genes, 12-0010 had weasel DNA, while 5-1101 did not. In terms of lineage, 5-1101 had weasel lineage, whereas 12-0010 did not. Similarity and lineage both predicted that participants would more often accept 5-1101 than 12-0010. The gene-based categorization predicted the opposite response pattern. Similarly, when the question category was squirrels, the comparison of exemplars 5-1101 and 12-0010 could also examine the basis of categorization. To comprehensively analyze the effects of between-group questioning way of categorization and within-group exemplar differences, we used binary logistic regression in GEE (Generalized Estimating Equation).

The results showed that when the question category was weasels, for the comparison of paired exemplars (5-1101 vs. 12-0010), the main effect of questioning way (between-group) was significant (Wald χ^2 (1) = 15.993, $p < .001$), with acceptance rates of exemplars being significantly lower in factual categorization than in modal categorization. The main effect of exemplars (within-group) was significant (Wald χ^2 (1) = 26.296, $p < .001$), with the difference direction predicted by genes (5-1101 < 12-0010). The interaction effect of the two factors was not significant (Wald χ^2 (1) = 3.095, $p = .079 > .05$).

When the question category was squirrels, for the comparison of paired exemplars (5-1101 vs. 12-0010), the main effect of between-group questioning way was not significant (Wald χ^2 (1) = 1.265, $p = .261 > .05$). However, the overall acceptance rate of the exemplars was lower in factual categorization than in modal categorization. The main effect of exemplars (within-group) was significant (Wald χ^2 (1) = 12.852, $p < .001$), with the difference direction predicted by genes (5-1101 > 12-0010). The interaction effect was not significant (Wald χ^2 (1) = .830, $p = .362 > .05$).

In sum, for the paired exemplars 5-1101 and 12-0010, whether the question category was weasels or squirrels, between-group questioning way of categorization and within-group exemplars both

affected the acceptance rates of exemplars. The modal categorization condition yielded more acceptances of these two exemplars than the factual categorization condition. Whether factual or modal categorization, these two exemplars were primarily based on genes rather than similarity and lineage. This shows that, in biological categorization, genes are a more fundamental essence than lineage, favoring the genes-dominated categorization hypothesis.

Finally, we merged the results of the extreme exemplars. For example, we merged the results of judging extreme exemplars 8-0101, 10-1100, and 11-1001 as weasels. The merging method for all other categories of exemplars was the same. We used the chi-square independence test to examine the influence of questioning way on range of variation of exemplars. The statistical data for each category of extreme exemplars and the results of the chi-square independence test for between-group differences are presented in Table 4.

Table 4

Acceptance frequencies (rates) of extreme exemplars and the result of Chi-Square independence test in Experiment 1

	Extreme exemplars	Factual Categorization	Modal Categorization	The results of Chi-Square Independence Tests for between-group differences
Weasels' extreme exemplars	Classifying marginal exemplars (8-0101、10-1100、11-1001) as weasels	29 (16.1%)	72 (40%)	χ^2 (1) = 25.446, p = .000 < .001, φ = .266
	Classifying exemplars (13-0100、14-0001、15-1000) as weasels	13 (7.2%)	48 (26.7%)	χ^2 (1) = 24.179, p = .000 < .001, φ = .259
Squirrels' extreme exemplars	Classifying marginal exemplars (6-0110、7-0011、9-1010) as squirrels	26 (14.4%)	79 (43.9%)	χ^2 (1) = 37.768, p = .000 < .001, φ = .324
	Classifying exemplars (2-0111、3-1110、4-1011) as squirrels	17 (9.4%)	51 (28.3%)	χ^2 (1) = 20.959, p = .000 < .001, φ = .241

The results of the chi-square independence test in Table 4 indicated that for each type of exemplars in the same row, the acceptance rates in modal categorization were significantly higher than those in factual categorization. This suggested that in factual categorization, participants were more constrained by essential properties of question categories and accepted extreme exemplars less frequently. In contrast, in modal categorization, participants were less constrained by essential properties of question categories and accepted extreme exemplars more frequently. Overall, for a question category modal categorization allowed a greater range of variation of exemplars (a broader category extension) than factual categorization, meaning that people were more likely to judge extreme exemplars without essential properties to be possible. This finding supported the possibility priming hypothesis.

Experiment 2

Method

Participants. The aim of this experiment was to explore the influence of causal accessibility among category properties on modal categorization. The sample size calculation was similar to that of Experiment 1. By setting the medium effect size $W = 0.3$, and according to statistical requirements ($\alpha = .05$, $power = 1 - \beta = .90$), we calculated that a total of at least 117 participants were needed for the two experimental conditions. To ensure statistical power, we recruited 256 college students (77 males and 179 females) from XXX university. They had not taken any logic courses. They were randomly arranged to two groups, with 128 participants in each group.

Design and Materials. Experiment 2 used a single-factor (causal accessibility: causally accessible condition vs. causally inaccessible condition) between-group design. The causally inaccessible condition used the same questionnaires as the modal categorization questionnaires in

Experiment 1, which contained no explicit presentation of causal relations. The causally accessible condition used the questionnaire with the explicit presentation of causal relations among category properties (see the causally accessible questionnaire in the appendix as supplementary materials). The presentation order of exemplars was counterbalanced in each condition, resulting in four questionnaires (C1, C2, D1, and D2). The complete questionnaire content can be found in the appendix. The encoding of animal individuals and the definition of exceptional exemplars were identical to those in Experiment 1. To make the task unambiguous, the causally accessible questionnaire defined every property, explained that an arrow between two properties denotes a causal relation and that an arrow marked with "×" denotes the absence of a causal relation, and stated explicitly that the diagram depicts the causal relations holding among an individual's properties. Participants were required to use this information when judging whether each imaginary individual is possibly a weasel or a squirrel.

Hypothetical predictions. Neither psychological essentialism nor similarity-based categorization was formulated for modal questions, so neither makes a prediction about the influence of causal accessibility. The possibility orientation hypothesis supplies that prediction. The possibility orientation hypothesis predicted that the causally accessible condition would yield more acceptances of extreme exemplars without the question category's genes than the causally inaccessible condition would.

Procedure. The procedure was the same as in Experiment 1.

The datasets of the present experiments are available at the link mentioned in the cover letter.

Results

The results of category judgments are shown in Table 5.

The extreme exemplars were merged using the same method as in Experiment 1. We used the chi-square test of independence to examine the influence of causal accessibility on modal categorization. The statistical data of extreme exemplars and the results of the chi-square tests of independence for between-group differences are presented in Table 6.

Table 5

Acceptance frequencies (rates) of 16 exemplars in question categories in Experiment 2

Exemplars	Causally-inaccessible condition		Causally-accessible condition	
	Weasels	Squirrels	Weasels	Squirrels
1-1111	124 (96.9%)	7 (5.5%)	127 (99.2%)	3 (2.3%)
2-0111	108 (84.4%)	22 (17.2%)	113 (88.3%)	18 (14.1%)
3-1110	101 (78.9%)	44 (34.4%)	81 (63.3%)	44 (34.4%)
4-1011	110 (85.9%)	38 (29.7%)	118 (92.2%)	12 (9.4%)
5-1101	68 (53.1%)	88 (68.8%)	45 (35.2%)	60 (46.9%)
6-0110	106 (82.8%)	51 (39.8%)	87 (68%)	36 (28.1%)
7-0011	109 (85.2%)	45 (35.2%)	108 (84.4%)	26 (20.3%)
8-0101	66 (51.6%)	97 (75.8%)	41 (32%)	90 (70.3%)
9-1010	103 (80.5%)	68 (53.1%)	90 (70.3%)	35 (27.3%)
10-1100	46 (35.9%)	111 (86.7%)	28 (21.9%)	108 (84.4%)
11-1001	52 (40.6%)	104 (81.3%)	38 (29.7%)	74 (57.8%)
12-0010	102 (79.7%)	71 (55.5%)	54 (42.2%)	49 (38.3%)
13-0100	29 (22.7%)	109 (85.2%)	24 (18.85%)	108 (84.4%)
14-0001	51 (39.8%)	107 (83.6%)	48 (37.5%)	83 (64.8%)
15-1000	16 (12.5%)	119 (93.0%)	13 (10.2%)	120 (93.8%)
16-0000	7 (5.5%)	126 (98.4%)	7 (5.5%)	123 (96.1%)

Note. For each condition, $N = 128$.

Table 6 showed that in each of the first, third, and fourth rows, the causally accessible condition

yielded less acceptances of extreme exemplars than the causally inaccessible condition. For extreme exemplars in the second row, acceptance rates showed no significant difference between the two conditions. Thus, the causally inaccessible condition yielded more acceptances of extreme exemplars based on WEPs without causal constraints, whereas the causally accessible condition yielded more rejections of extreme exemplars based on SEPs with causal constraints. This result supported the prediction of the possibility orientation hypothesis.

Table 6

Acceptance frequencies (rates) of extreme exemplars and the result of Chi-Square independence test in Experiment 2

	Extreme exemplars	The causally inaccessible condition	The causally accessible condition	The results of Chi-Square tests for between-group Differences
Weasels' extreme exemplars	Classifying marginal exemplars (8-0101、10-1100、11-1001) as weasels	164 (42.7%)	107 (27.9%)	χ^2 (1) = 18.526, p = .000 < .001, φ = .155
	Classifying atypical squirrel exemplars (13-0100、14-0001、15-1000) as weasels	96 (25%)	85 (22.1%)	χ^2 (1) = .875, p = .350 > .05, φ = .034
Squirrels' extreme exemplars	Classifying marginal exemplars (6-0110、7-0011、9-1010) as squirrels	164 (42.7%)	97 (25.3%)	χ^2 (1) = 26.053, p = .000 < .001, φ = .184
	Classifying atypical weasel exemplars (2-0111、3-1110、4-1011) as squirrels	104 (27.1%)	74 (19.3%)	χ^2 (1) = 6.582, p = .010 < .05, φ = .093

We further examined the influence of upstream versus downstream causal relations on categorization of untypical exemplars with question category genes: whether modal categorization was based on matching upstream or downstream causal relations in the question category causal network. Causal matching patterns of untypical exemplars could be divided into two types. One

type had causal networks where upstream causal relations matched respective causal laws in prototypes, but downstream causal relations had one mismatch and one match with prototypes. The other type had causal networks where upstream causal relations were mismatched, but downstream causal relations were matched. Each type had one causal mismatch with prototypes. When weasels were the question category, exemplars 2-0111 and 4-1011 matched the weasel prototype (like exemplar 1-1111) in upstream causal relations (sharing the causal law that weasels' lineage causes weasels' DNA), but there was one mismatch (weasels' DNA does not correspond to weasels' appearance or internal anatomy) in downstream causal relations, while exemplar 3-1110 mismatched the weasel prototype in upstream causal relations, but matched the weasel prototype in downstream causal relations. The prediction based on upstream causal matching was that the acceptance rate of 2-0111 would be higher than that of 3-1110 and that the acceptance rate of 4-1011 would be higher than that of 3-1110. The prediction based on downstream causal matching was that the acceptance rate of 2-0111 would be lower than that of 3-1110 and that the acceptance rate of 4-1011 would be lower than that of 3-1110. Similarly, when the question category was squirrels, the basis for modal categorization could also be examined by comparing 13-0100 vs. 14-0001 and comparing 15-1000 vs. 14-0001. To comprehensively analyze the effects of the between-group variable causal accessibility and the within-group variable causal matching patterns, we used binary logistic regression in GEE.

The results showed that when the question category was weasels, for each comparison of paired exemplars (2-0111 vs. 3-1110 and 4-1011 vs. 3-1110), the main effect of causal accessibility (between-group differences) was not significant (2-0111 vs. 3-1110: Wald χ^2 (1) = .874, p = .350 > .05; 4-1011 vs. 3-1110: Wald χ^2 (1) = .052, p = .819 > .05). The main effect of causal matching patterns (within-group differences) was significant (2-0111 vs. 3-1110: Wald χ^2 (1) =

16.391, $p < .01$; 4-1011 vs. 3-1110: Wald χ^2 (1) = 23.659, $p < .01$). The direction of the difference in acceptance rates for the two exemplars aligned with the direction predicted by upstream causal relations (2-0111 > 3-1110; 4-1011 > 3-1110). The interaction effect of the two factors was significant (2-0111 vs. 3-1110: Wald χ^2 (1) = 5.929, $p < .05$; 4-1011 vs. 3-1110: Wald χ^2 (1) = 8.332, $p < .01$). To further test the simple effects, we conducted binary logistic regression analyses on the acceptance rates of exemplars in each of causally inaccessible and causally accessible conditions. The results indicated that in the causally inaccessible condition, for each comparison of paired exemplars (2-0111 vs. 3-1110 and 4-1011 vs. 3-1110), causal matching patterns did not influence acceptance rates of these exemplars (2-0111 vs. 3-1110: Wald χ^2 (1) = 1.583, $p = .208 > .05$; 4-1011 vs. 3-1110: Wald χ^2 (1) = 2.614, $p = .106 > .05$). In the causally accessible condition, causal matching patterns significantly affected acceptance rates of these exemplars (2-0111 vs. 3-1110: Wald χ^2 (1) = 12.318, $p < .001$; 4-1011 vs. 3-1110: Wald χ^2 (1) = 18.300, $p < .001$). The directions of the differences in acceptance rates aligned with the directions predicted by the upstream causal relations (2-0111 > 3-1110; 4-1011 > 3-1110).

When the question category was squirrels, for the comparison of paired exemplars (13-0100 vs. 14-0001), the main effect of causal accessibility (between-group) was significant (Wald χ^2 (1) = 4.722, $p < .05$). For the comparison of paired exemplars (15-1000 vs. 14-0001), the main effect of causal accessibility was not significant (Wald χ^2 (1) = 2.109, $p = .146 > .05$). For each comparison of paired exemplars (13-0100 vs. 14-0001 and 15-1000 vs. 14-0001), the main effect of causal matching patterns (within-group) was significant (13-0100 vs. 14-0001: Wald χ^2 (1) = 7.943, $p < .01$; 15-1000 vs. 14-0001: Wald χ^2 (1) = 29.741, $p < .001$). The direction of the difference in acceptance rates for the two exemplars aligned with the prediction by upstream causal relations (13-0100 > 14-0001; 15-1000 > 14-0001). The interaction effects of the two factors were significant

(13-0100 vs. 14-0001: Wald χ^2 (1) = 5.098, p < .05: 15-1000 vs. 14-0001: Wald χ^2 (1) = 4.173, p < .05). To further test the simple effects, we conducted binary logistic regression analyses on the acceptance rates of exemplars in each condition. The results indicated that in the causally inaccessible condition, for the comparison of paired exemplars (13-0100 vs. 14-0001), causal matching patterns did not influence acceptance rates of these exemplars (Wald χ^2 (1) = .182, p = .670 > .05); for the comparison of paired exemplars (15-1000 vs. 14-0001), causal matching patterns significantly affected acceptance rates of these exemplars (Wald χ^2 (1) = 7.076, p < .01). However, overall, acceptance rates for both exemplars exceeded 80%. In the causally accessible condition, for each comparison of paired exemplars (13-0100 vs. 14-0001 and 15-1000 vs. 14-0001), causal matching patterns significantly affected acceptance rates of these exemplars (13-0100 vs. 14-0001: Wald χ^2 (1) = 11.338, p < .01; 15-0100 vs. 14-0001: Wald χ^2 (1) = 23.852, p < .001). The direction of the difference in acceptance rates aligned with the direction predicted by upstream causal relations (13-0100 > 14-0001; 15-1000 > 14-0001).

Overall, for the above untypical exemplars, in the causally inaccessible condition, causal matching patterns did not influence the acceptance rates of these untypical exemplars, suggesting that modal categorization was independent of causal constraints. However, in the causally accessible condition, causal matching patterns significantly affected acceptance rates of these exemplars. The direction of the difference in acceptance rates aligned with the direction predicted by the upstream causal relations. This suggested that modal categorizations were affected by causal constraints.

In summary, the results of Experiment 2 showed that causal accessibility significantly affected modal categorizations. Modal categorization was more likely to be constrained by causal laws in the causally accessible condition than in the causally inaccessible condition. Moreover, in the causally

accessible condition rather than the causally inaccessible condition, causal matching patterns significantly affected acceptance rates of exemplars, with the direction of the difference predicted by whether upstream causal relations matched. The overall response pattern of modal categorization favors the possibility orientation hypothesis.

General Discussion

Experiment 1 showed that the modality of the categorization question affected categorization. Compared with factual questions, modal questions primed participants to go beyond the constraints of the essential properties of the question categories and to accept more exceptional exemplars, indicating a greater range of variation of category exemplars (a broader category extension). This suggests that modal questions can activate thinking about possibilities beyond the constraints of essential properties. Such possibilities are weak in a broader sense. Consistent with the epistemic sense of possibility adopted here, participants treat these further exemplars as compatible with their knowledge rather than as real-worldly feasible or as metaphysically required. Therefore, modal categorization has a character that factual categorization cannot capture, and factual questions alone cannot adequately probe people's modal understanding of category properties. This is a new finding that broadens the perspective of categorization research.

Experiments 1 and 2 consistently showed that, in both factual and modal categorization, participants' predominant responses to the exemplars depended on whether those exemplars possessed the genes of the category in question. Thus, most participants believed that genes, rather than other properties, were the fundamental essential property that determined membership in animal categories. Among the multiple essential properties, an individual's gene system primarily affected modal categorization. This finding aligns with previous findings on psychological

essentialism (Barton & Komatsu, 1989; Gelman, 2004; Neufeld, 2022; Sloman & Ahn, 1999). These findings support psychological essentialism about natural categories.

In contrast, a minority of responses were not constrained by the genes of the category in question, indicating that these participants believed that genes do not determine membership in animal categories. Thus, participants showed individual differences in modal categorization. While psychological essentialism could explain the gene-dominated responses, it failed to explain the minority responses.

Experiment 2 further revealed that causal accessibility, as a real-world condition, affected the possibility orientation of modal categorization. Compared with the causally inaccessible condition, modal categorization in the causally accessible condition was more constrained by real causal laws, with participants less likely to judge exceptional and untypical exemplars that violated causal laws to be possibly individuals of the question categories. This suggests that, in the causally inaccessible condition, modal categorization relied more on WEPs without causal constraints, whereas in the causally accessible condition it relied more on SEPs with causal constraints. Thus, the possibility orientation of modal categorization (WEP versus SEP) varied with causal accessibility. This is a new finding beyond previous research. This finding suggests that whether causal laws affect categorization is modulated by causal accessibility.

Moreover, Experiment 2 found that, in the causally accessible condition, modal categorizations for untypical exemplars that violated causal laws of question category properties depended on whether upstream causal relations (rather than downstream causal relations) matched causal laws. This indicated that upstream causal relations had a greater impact on modal categorizations than downstream causal relations did. This suggests that the positions of causal relations among properties affected modal categorization. This finding aligns with previous evidence that category

properties that are upstream in causal networks play greater roles in factual categorization (Ahn & Lassaline, 1995; Luhmann et al., 2006; Rehder & Hastie, 2001). In the causally inaccessible condition, whether upstream and downstream causal relations match causal laws did not affect modal categorizations of untypical exemplars that violated causal laws of question category properties; thus, positions of causal relations did not affect modal categorizations of untypical exemplars. This was because participants lacked access to the causal relations among properties and so could not further distinguish their positions. Overall, whether the positions of causal relations affect modal categorization depends on causal accessibility and is therefore relative. This is also a new finding.

In summary, Experiment 2 shows that whether causal relations affect modal categorization depends on causal accessibility, and is therefore relative. Causal laws affect modal categorization when causal knowledge is accessible. In cases where causal knowledge is inaccessible, causal relations generally do not affect modal categorization. In some natural situations, people may not be able to think of relevant causal knowledge, and so they fail to categorize based on causal laws. Previous findings that causal laws affect categorization are thus specific and lack general significance. Therefore, modal categorization is not necessarily constrained by causal laws.

Experiment 2 also revealed that although participants accepted untypical exemplars that violated causal laws less frequently in the causally accessible condition than in the causally inaccessible condition, most participants still accepted untypical exemplars that possessed the genes of the question categories despite violating causal laws. Therefore, in the causally accessible condition, genes of question categories played the primary role in modal categorization, while the influence of causal laws was secondary. Causal laws served only as supplementary restrictions on modal categorization, with only a minority of participants taking causal constraints into account and

rejecting untypical exemplars that possessed the genes of the question categories but violated causal laws. In summary, in the causally accessible condition, modal categorization based on causal laws served merely as a limited supplement to the gene-dominated categorization.

Some might argue that the limited influence of causal laws on modal categorization may be due to the labeling effect from the present category property settings. Specifically, if a property of an exemplar is labeled with a category label, participants would tend to judge the exemplar to be possibly an individual of that category without considering whether it violated causal laws. However, the labeling effect account cannot explain the response patterns of marginal exemplars. In the four properties labels of each marginal exemplar, the number (2) of weasel labels and the number (2) of squirrel labels were equal. According to the labeling effect account, each marginal exemplar should be categorized as either a weasel or a squirrel with equal probability. Contrary to this prediction, most modal categorizations of each marginal exemplar were based on its genes, regardless of the category labels of the other properties. This result showed that when each property of an exemplar carried a category label, the labels associated with the properties did not act as independent diagnostic features that could facilitate categorization; instead, categorization relied on the properties rather than on the labels. This finding disfavors the labeling effect account, and so differs from the previous finding favoring the label-feedback hypothesis that the presence of category labels as diagnostic features generally facilitates categorization by activating label-related schemas (Gervits et al., 2023; Johanson & Papafragou, 2016; Lupyan, 2012; Nedergaard, et al., 2023; Price, et al., 2022). The difference suggests that whether category labels affect categorization depends on whether the labels are independent of the category properties. This question is worthy of future exploration.

Experiment 2 also suggests that the positions of properties in causal structures affect their status

in categorization. In the causal structures of weasels and squirrels, genes in central positions are central properties (with the most associated causal relations), while lineage, appearance, and internal anatomy are peripheral properties (with fewer associated causal relations). In the causally accessible condition, the dominant responses to exemplars aligned with the predictions of the central property genes rather than with the predictions of other properties. This indicates that the central property (genes) dominated categorization and had a greater impact than the peripheral properties. This is consistent with similar previous findings (Luhmann et al., 2006; Rehder & Hastie, 2001). Furthermore, in causal relations where lineage leads to genes, the position of lineage is before the position of genes. In this case, causal orders of properties predict that the influence of lineage on categorization would be greater than that of genes. Conversely, centrality of properties predicts that the influence of lineage on categorization would be smaller than that of genes. The results of Experiment 2 aligned with the latter rather than the former. This suggests that in situations where causal orders of properties conflict with property centrality, centrality of properties dominates categorization, thus trumping the influence of causal orders of properties. This suggests that the influence of causal orders of properties may be modulated by property centrality and is therefore not necessary.

The present results only partially support Rips' view (2001, 2011) that the main factors affecting the modal status of natural kinds are people's understanding of the essential properties of natural categories and the interaction of properties (including causal laws). In both experiments, although genes dominated modal categorizations of untypical exemplars, a considerable proportion of participants accepted exceptional exemplars without question categories' genes, demonstrating a violation of psychological essentialism. This individual difference suggests that essential properties are not a necessary or universal factor in modal categorization. This is consistent with previous

findings that essentialist intuitions about the identity of kinds are easily malleable (Haukioja et al., 2021; Machery et al., 2023; Malt, 1993).

The results of Experiment 2 demonstrated that in the causally inaccessible condition, whether or not causal relations among exemplar properties matched causal laws did not affect modal categorization, and most participants categorized according to whether exemplars possessed the genes of the question categories. Since causal laws are the foundation of the interaction of category properties, these modal categorizations were not based on an understanding of the interactions between properties. The predominant modal categorization merely depended on genes, without being constrained by real causal laws or property interactions. Thus, such modal categorization reflects the WEP reading, rather than the SEP reading, of category exemplars. Consequently, understanding the interaction of category properties is not necessary for modal categorization of natural categories.

Conclusion

The present two experiments demonstrate the three main hypotheses/effects of modal categorization: (1) the possibility priming hypothesis/effect, whereby modal categorization allows a greater range of variation of possible exemplars within a category than factual categorization does, indicating a broader category extension; (2) the possibility orientation hypothesis/effect that modal categorizations are more likely to be based on SEPs with causal constraints in the causally accessible condition than in the causally inaccessible condition, resulting in fewer acceptances of exceptional exemplars that indicated a narrower category extension; (3) the genes-dominated categorization hypothesis/effect, whereby, among the multiple properties of a biological category, an individual's DNA dominates modal categorization even when its other properties do not causally coordinate with its DNA. These effects pose challenges to the main existing accounts of the modal

status of natural kinds and shed light on a modal perspective in categorization research.

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supplementary materials

APPENDIX

The causally accessible condition questionnaire (D1) (English version)

Instructions

Welcome to this experiment. Please read the following task carefully and complete the items in order.

The following pictures present two mammal species; weasels and squirrels. Table 1 lists the properties of these two kinds of animals. Above Table 2, causal relations between properties are shown separately for the two animal species, and Table 2 presents the causal relations of imaginary animal individuals. In these diagrams, arrows denote causal relations between properties, whereas arrows marked with "×" indicate that there are no causal relations between properties. In other words, an arrow from one property to another means that the first property causally gives rise to the second, whereas a "×" between two properties means that they are not causally related. According to the information provided, please judge whether each imaginary animal in Table 2 is possibly a weasel or a squirrel. In the last two columns of Table 2, place a check mark (√) in one of options "Yes" and "No" to indicate your judgment.

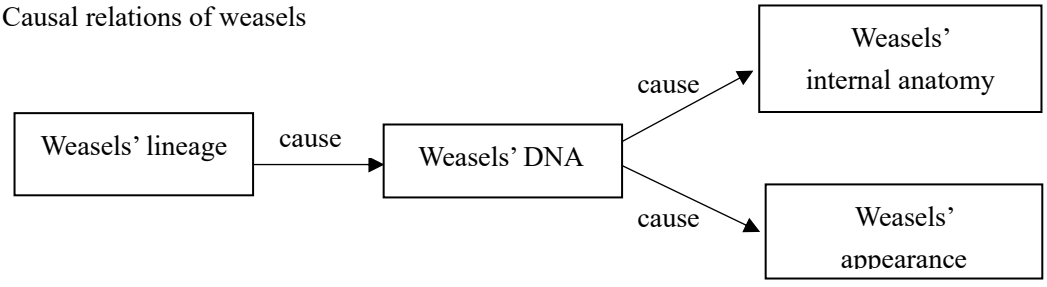




Table 1 Properties of weasels and squirrels

Properties	Weasels	Squirrels
Appearance	Slender, elongated bodies with yellow fur. Long snouts, no ear tufts, big and bright eyes. Short limbs, and long, thin tails.	Small, round bodies with black and reddish-brown fur. Short snouts, with ear tufts. long limbs, and thick, bushy tails.
Internal anatomy	With weasels' internal anatomy.	With squirrels' internal anatomy.
Gene system	With weasels' DNA.	With squirrels' DNA.
Lineage	Offspring are produced viviparously through mating between male and female weasels.	Offspring are produced viviparously through mating between male and female squirrels.

Causal relations of weasels



Causal relations of squirrels

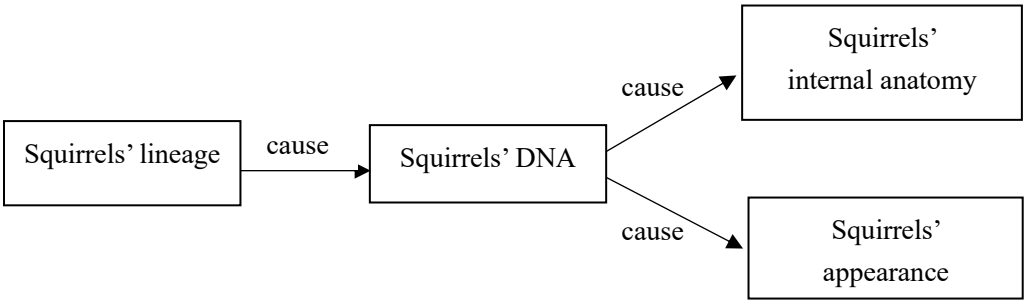
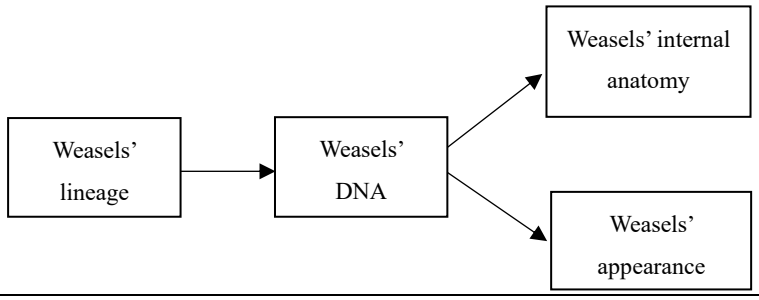
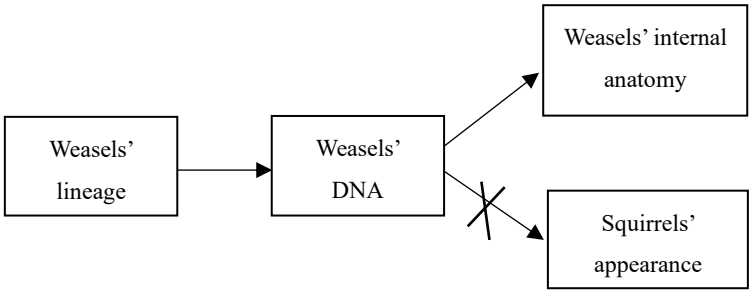
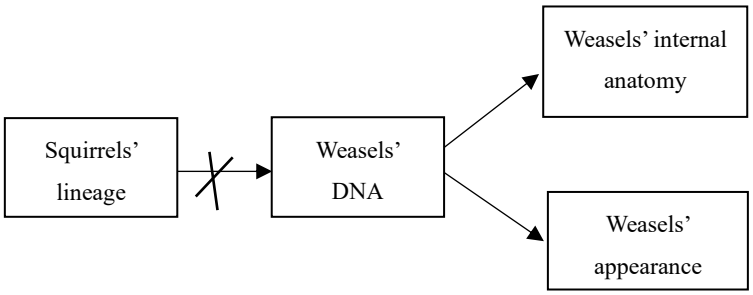
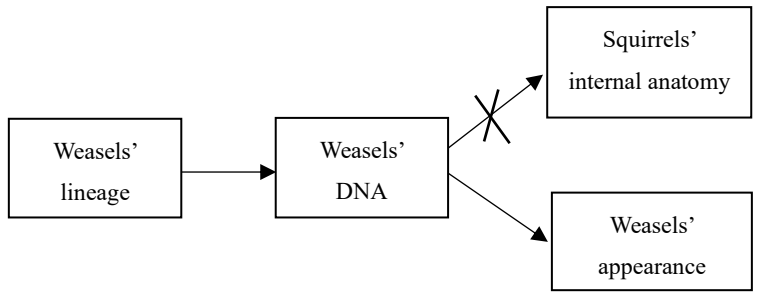
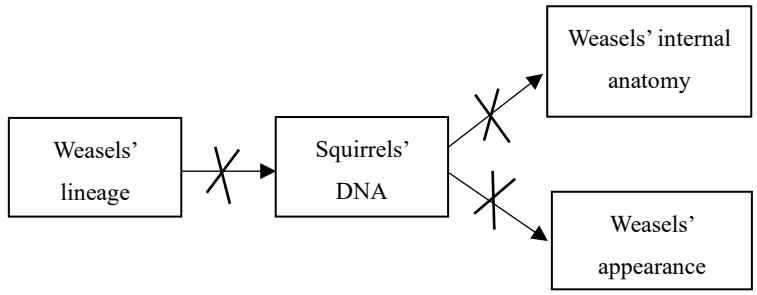
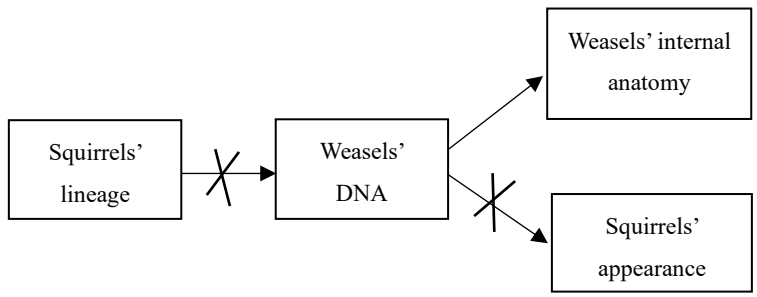
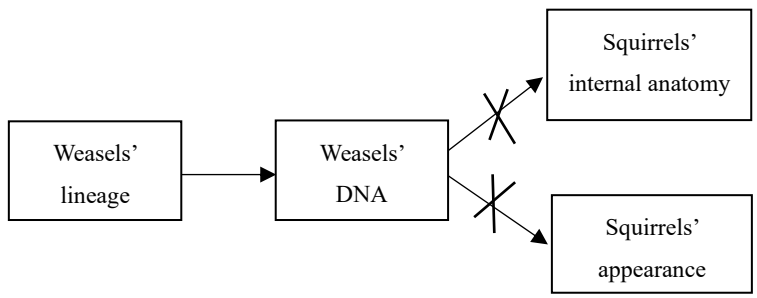
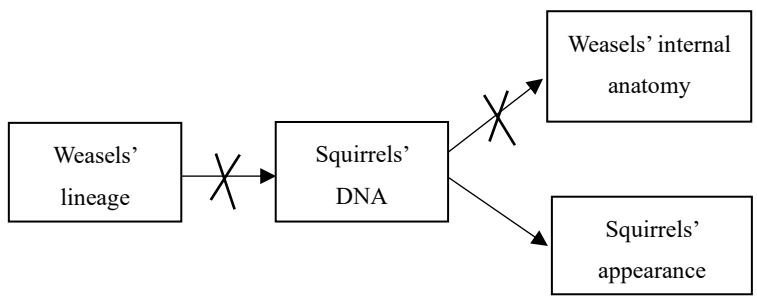
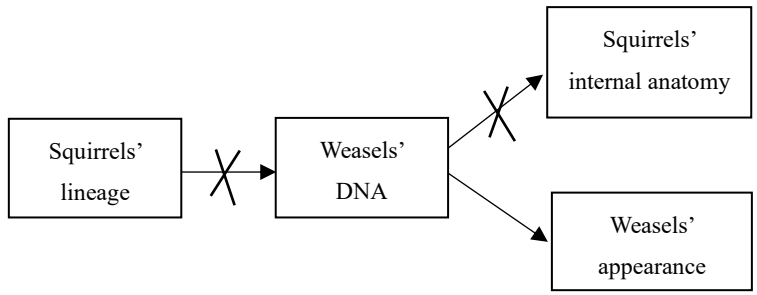
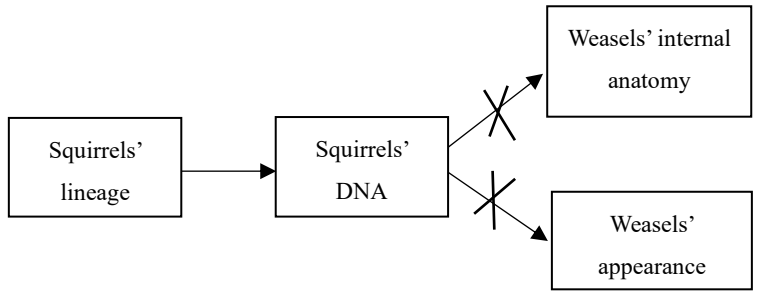
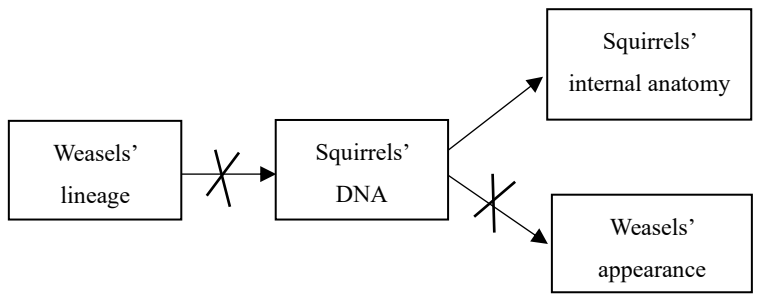
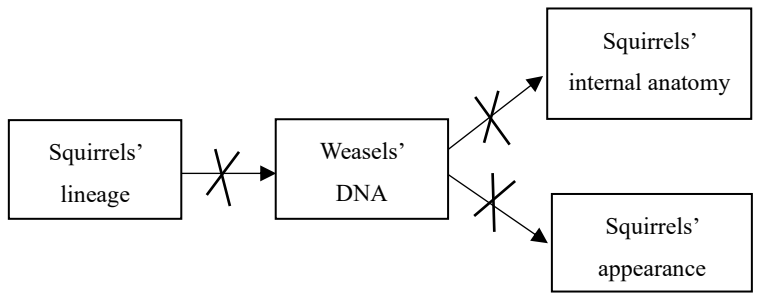
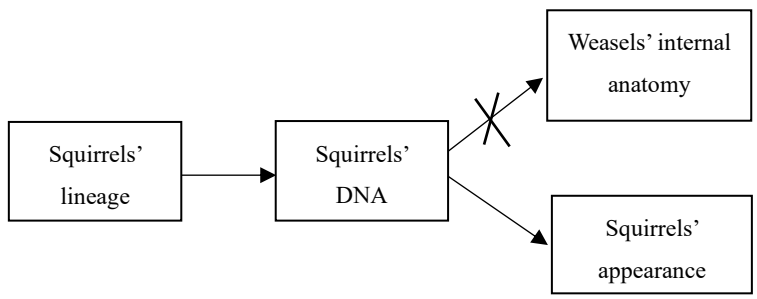
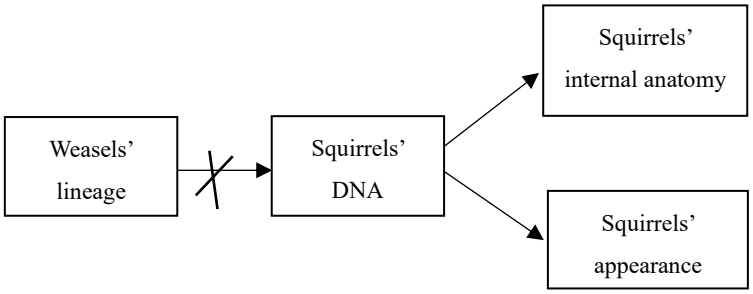
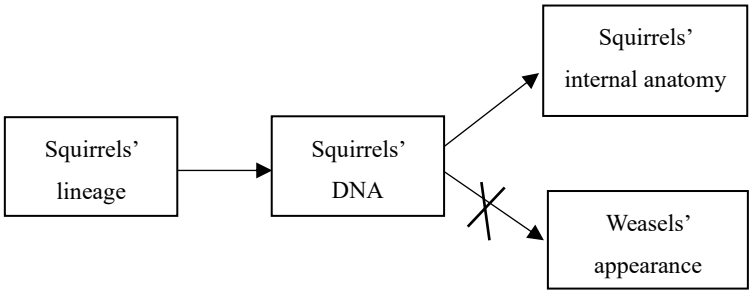
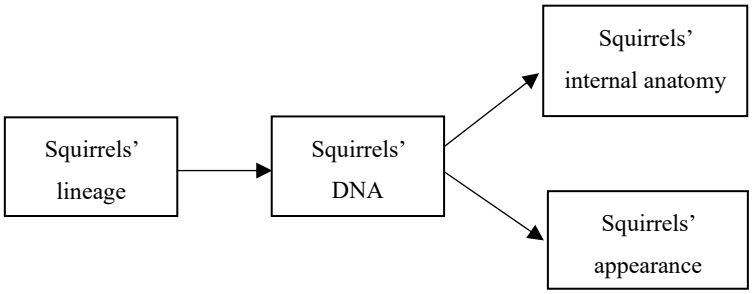


Table 2 Please judge whether each imaginary individual in the list below is possibly a weasel or a squirrel. (The arrows indicate causal relations between properties, and arrows marked with "×" indicate that there are no causal relations between properties)

Imaginary animal individual	Causal relations of individuals' properties	Is this animal possibly a weasel?	Is this animal possibly a squirrel?
Animal 1		Yes No	Yes No
Animal 2		Yes No	Yes No
Animal 3		Yes No	Yes No

Animal 4		Yes No	Yes No
Animal 5		Yes No	Yes No
Animal 6		Yes No	Yes No
Animal 7		Yes No	Yes No
Animal 8		Yes No	Yes No

Animal 9		Yes No	Yes No
Animal 10		Yes No	Yes No
Animal 11		Yes No	Yes No
Animal 12		Yes No	Yes No
Animal 13		Yes No	Yes No

Animal 14 	Yes No	Yes No
Animal 15 	Yes No	Yes No
Animal 16 	Yes No	Yes No