Naturally-formed objects categorized as artifacts: Effect of objects' functional depictions

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Past research has identified a variety of factors that influence cognitive processing of artifact concepts, but few experiments tested possible interactive patterns among these factors. Using a natural language depiction based free naming task, we explored how an object's function and its history (information about how an object was formed by natural force) interact to affect categorization judgment in a 2×2 between- subjects experiment ($N = 169$). The study had two key findings: (i) Without presenting an object's function, presenting the history of its natural formation increased subjects' tendency to name the object under the "natural" domain and decreased their tendency to name it under the "artifact" domain; (ii) once we presented the depiction of an object's function, the effect of history presentation on categorization disappeared: Subjects in both conditions strongly preferred naming objects as artifacts. In summary, presenting depiction of an object's function inhibited the effect of history on object categorization. Current findings suggest that an object's function plays a fundamental role in the cognitive processing of artifact concepts.

artifacts, categorization, design, history, function

In daily life, there are numerous kinds of artifacts that people often use, such as chairs, tables, books, pens, computers, and so on. Several lines of research have provided converging evidence that the cognitive systems for acquiring, representing and processing knowledge of artifacts (e.g. tools and vehicles) are distinct from those systems for natural kinds (e.g. animals and plants) [1–3] (see ref. [4] for a review). What is the key component in conceptual representation and the processing mechanisms of artifact concepts?

A theoretical debate on this topic in cognitive psychology has lasted for 2 decades. In early views, some theorists considered the understanding of object's function as the key factor in the representation and processing of artifact concepts [5–7]. Other theorists, however, did not consider function as a crucial factor for the representation of artifact concepts, and proposed that other properties of objects have the same role (even more important) in artifact concepts representation and processing [8]. Recently, an influential "design-based view" [9,10] theory was developed based on the latter opinion, which claims that the understanding of an agent on other's mental state (i.e. the Creator's intended design for the object) determines artifact concepts processing. On the other side, a "utility-based" [11,12] theory was developed on the former opinion, which considers the understanding of the interactive relation between an agent and an object to be the key component in artifact concept representing and processing. Object's function works as a cue to guide the agent in understanding of the "using-goal" of the object. Thus, an object's function makes the artifact a unified, coherent conceptual whole to the agent.

Theory debate stimulated many researchers to test different hypotheses. However, possible confounding between independent variables and extraneous variables made the truth unclear, although several factors were found to affect

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the processing of the artifact concept [9,10,13–22] (see ref. [10] for a selective review). Besides, different findings conflict with each other, although confounding variables were well controlled. For example, an important finding for the design-based view is Gelman and Bloom's experiment [22]. They found different histories of an ambiguous object made subjects class object into different domains. Using free naming task, experimenters showed some ambiguous objects to 3-, 4-, and 5-year-old children and adults, described two conditions of history (intended vs. accidental) of the objects, and asked them to name the objects. Results showed that both young children and adults named objects as artifacts more in the intended condition than those in the accidental condition. In this experiment, no functional information was explicitly presented to subjects. It is reasonable for the authors to consider the results as evidence for the design-based theory. On the contrary, Asher and Kemler Nelson [13] found objects' function plays an important role in children's understanding of artifacts. They presented objects to 3- and 4-year-olds and presented them objects' functions (plausible or implausible). They encouraged children to ask questions about the object and then measured the number of the questions they asked. Results showed that children asked more questions in the implausible condition than those in the plausible condition. This finding provided evidence for the utility-based theory.

Controversial opinions and studies suggest the need to clarify the relationship between object's history and function. We explored it in a 2×2 factorial design study. We manipulated "history" as an IV by presenting a depiction about how an object was naturally-formed, and manipulated "function" by presenting a depiction about how an object was used in some certain way or not. A key point in this design is that naturally-formed objects are not "artifacts" but have certain functions suggesting it is an artifact. In this way, the two kinds of information compete when presented simultaneously to one group of subjects. Subjects' reactions would differentiate the two competing theories because the two sides of theories in debate have different predictions for the results.

If the design-based view is correct (i.e. object's history has effect on artifact categorization but function has not), the result of the experiment would be either of the following two: (1) History and function both have a main effect but no interaction; or (2) history and function interact and the pattern is that history inhibits function's effect on categorization; specifically, function would have effect on artifact categorization in the condition when history of natural-formation was not presented, but no effect when such history was presented. On the contrary, if the utility-based view is correct, the result would show another pattern: Object's history should have an effect on artifact categorization in condition where function was not presented but history should have no effect where function was not presented.

1 Method

1.1 Participant

Totally, 169 college students (76 males and 93 females) participated in this experiment. They were from Zhejiang Sci-Tech University and on average 20.8 years old.

1.2 Material and design

Using free naming task, we shortly depicted the appearance and material of 6 items of ambiguous objects in natural language, and selectively presented objects' history and function in different conditions (see the complete depictions in Supplement on line 1). Below these words, subjects were asked to name the object and rate their confidence for each naming response. Participants were randomly assigned to one of the 4 groups in a 2 (history: present or not)×2 (function: present or not) between subject design.

1.3 Procedure

We conducted the pen and paper test in a quiet classroom. The booklet has 7 pages with 1 cover page and 6 test pages, with each item on one test page. The instruction explains the aim of this experiment is to investigate how people categorize objects but not to test intelligence. The test lasted for about 15–20 min.

2 Results

Each of all naming responses was marked with one of the 4 labels, according to the coding scheme categorizing names [9], for details see Supplement on line 2. The 4 labels are: Artifacts (name in artifact domain), Natural kinds (name in natural kind domain), Unclear (e.g. "things for telling fortunes"), and Invalid (e.g. "I don't know"). Inter-rater agreement, Cohen's Kappa, was 0.96. One subject had 3 invalid naming responses and his data was deleted. Finally, we had 168 valid participants (41, 45, 40 and 42, in each condition, respectively). In all 1008 naming responses, there were 942 valid (93.4%) and 66 invalid (including 43 missing within) ones.

2.1 Frequency of naming

Table 1 shows means (0 as lower bound and 6 as upper bound) and SE of frequency of the 4 kinds of naming responses in the four experimental conditions. A 2 (Naturally-formed history: present or not) × 2 (function: present or not) MANOVA was performed with frequency of naming as Artifact and Natural kind responses as dependent variables. We found a significant main effect of History, F (2,

Table 1   Means of frequency of 4 kinds of naming in the four conditions (with SE in the parentheses)

History	Function	Kinds of Naming			
		Artifacts	Natural kinds	Unclear	Invalid
Not presented	Not presented	2.78(0.24)	1.49(0.23)	1.22(0.18)	0.51(0.11)
	Presented	3.44(0.23)	0.51(0.22)	1.84(0.17)	0.20(0.10)
Presented	Not presented	1.73(0.24)	2.28(0.23)	1.35(0.18)	0.65(0.11)
	Presented	3.48(0.24)	1.07(0.23)	1.21(0.18)	0.24(0.11)

163) = 4.43, $P < 0.05$; a significant main effect of Function, $F(2, 163) = 15.00$, $P < 0.001$; and a significant interaction effect, $F(2, 163) = 3.37$, $P < 0.05$. These results showed a general pattern that both independent variables had effect on categorization judgments and they had an interaction. Below, we analyzed the data pattern in detail with A and N as DV, separately.

A 2 (Naturally-formed History: present or not) × 2 (Function: present or not) ANOVA was performed with frequency of Natural Kinds responses as dependent variables. Results showed a significant main effect of History, $F(1,164) = 8.76$, $P < 0.01$, which means presenting naturally-formed history increased *N* responses; and a significant main effect of Function, $F(1,164) = 22.93$, $P < 0.001$, which means presenting objects' function decreased *N* responses. No significant interaction was found, $F(1,164) = 0.25$, $P > 0.61$. There results showed that Function and History have separate effect on subjects' N naming responses (Figure 1).

A 2 (Naturally-formed History: present or not) × 2 (Function: present or not) ANOVA was performed with frequency of Artifact responses as the dependent variable. Results showed a significant main effect of History, $F(1,164) = 4.68$, $P < 0.05$, which means presenting naturally-formed history decreased A responses; a significant main effect of Function, $F(1,164) = 26.07$, $P < 0.001$, which means presenting objects' function increased A responses, and a significant interaction, $F(1,164) = 5.28$, $P < 0.05$, which means the two factors are not independent in their impact on Artifact responses. Together, these results showed that Function and History had separate effects on subjects' *N* naming responses (Figure 2).

Further, simple effect analyses showed two more results:
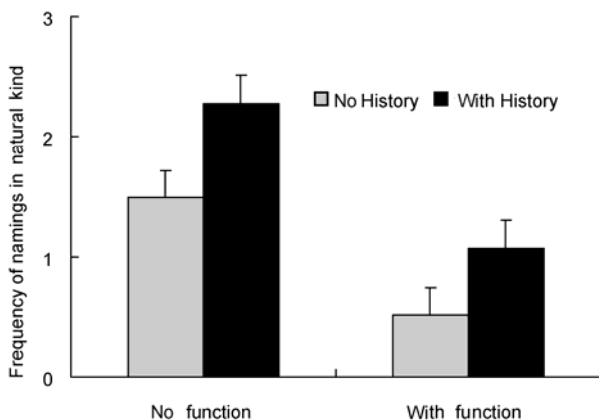
Figure 1   Means of N responses in 4 conditions (SE as the error bar).
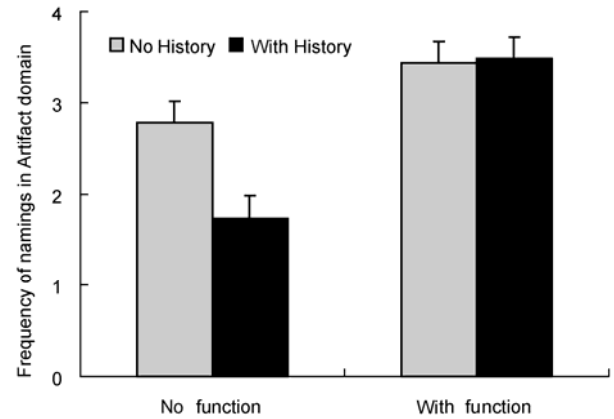
Figure 2   Means of A responses in 4 conditions (SE as the error bar).

(i) In conditions of not presenting Function, a significant difference was found between conditions of presenting naturally-formed History and not, $t(79) = 2.99$, $P = 0.004 < 0.01$; (ii) in conditions of presenting Function, no significant difference was found, $t(85) = -0.10$, $P = 0.92$. Such an interaction indicated that presenting an object's Function inhibited the effect of history on artifact categorization. On the contrary, presenting Function significantly increased A responses in both conditions presenting naturally-formed History and not, $t(84) = -2.12$, $P = 0.037 < 0.05$; $t(80) = -4.91$, $P < 0.001$. Such a result indicated that no reversal effect emerged, namely, presenting naturally-formed history did not inhibit objects' Function's effect.

2.2 Confidence of naming

Table 2 shows the means (and SE) of confidence for Artifact and Natural Kinds naming responses in the 4 experimental conditions.

A 2 (Function: presenting or not) × 2 (History: presenting or not) ANOVA was performed with A response as DV. Results showed that only Function had a significant main effect, $F(1,78) = 5.06$, $P = 0.027$. $F(1,78) = 2.95$, $P = 0.09$ and $F(1,78) = 0.02$, $P > 0.89$ for History and interaction, respectively. These results showed that presenting Function increased participants' confidence of naming experimental items as artifacts.

A 2 (Function: presenting or not) × 2 (History: presenting or not) ANOVA was performed with N response as DV. No significant effect was found. Specifically, $F(1,78) = 0.27$, $P > 0.60$; $F(1,78) = 2.89$, $P = 0.093$; and $F(1,78) = 0.04$, $P > 0.84$ were for History, Function and interaction, respect-

Table 2   Means of confidence of Artifact and Natural Kinds naming responses in the 4 experimental conditions (SE in the parentheses)

History	Function	Naming kinds	
		Artifact	Natural kind
Not presenting	Not presenting	5.82(0.29)	6.19(0.35)
	Presenting	6.53(0.37)	6.48(0.45)
Presenting	Not presenting	5.20(0.33)	5.58(0.39)
	Presenting	6.00(0.34)	5.72(0.41)

tively.

Generally, results of confidence rating were consistent with that of frequency of naming.

3   Discussion

In this study, we had two asymmetrical results. The first is that the artifact and non-artifact (natural kind) distinction does not work as a clear-cut boundary for the outcomes of a single underlying mechanism. Instead, categorization judgments for the two domains depend on different steps of cognitive processing. In our study, the two factors (i.e. history and function) were not simply opposing each other on artifact and natural kind categorization (which to some extent was assumed). Actually, the two variables had independent impact when subjects considered objects naming in natural kind domain but interacted in a complex way when subjects considered it in Artifact domain. Results of confidence rating were consistent with that in naming responses. No difference was found in confidence in subjects rating for natural kind naming responses but was for Artifact naming responses in conditions with or without presenting naturally-form history.

The second result is the interaction effect. Data showed that presenting Function inhibited the influence from history to artifact naming. In the condition of presenting both naturally-formed history and object's function, subjects were explicitly told that objects were formed by natural force but they still preferred to name the objects as artifacts. The naming frequencies in conditions of presenting "naturally-formed" history and not were almost exactly the same. Furthermore, when subjects considered whether to name the object as an artifact, they completely ignored the information of naturally-formed history once function was presented. On the contrary, subjects balanced both function and history information when they considered whether to name the object as a natural kind. These results suggest that being man-made is not necessary for the concept of the concrete objects (e.g. shield, raincoat, stove, etc.) in our everyday lives. Instead, man-made history seems to work indirectly as a clue to the key information (i.e. function) of the object concept. Once the key information emerges, the clue does not work any more.

The utility-based view predicted the above results, but the design-based view can hardly explain the data pattern. Subjects were explicitly told the objects were natu-

rally-formed but still named them into the artifact domain. This result indicated that artifact concept processing does not necessarily depend on "inferring creator's intended design".

In this study, a two-factor-competing paradigm was used. Relative to many previous studies which tested only one single factor's effect on artifact concept processes, this study took a next step to investigate the internal structure of artifact concepts. Many different factors were found in previous studies using single factor paradigm but the relationship among these IVs was hardly explored. Consequently, deeper theoretical questions could not be answered. For example, Matan and Carey [23] found object's original function is more important than the current function on artifact naming. They explained this phenomenon by the design-based theory with "children inferred creator's intent". However, they forgot the so-called creator's intent was presented indirectly through one kind of "function" (i.e. original function), instead of directly, in front of the faces of children in their experiment but. If the so-called intent was not consistent with any kind of function but had to compete with certain functional information, how will the children respond? They cannot predict the answer to such a question because they did not separate the two variables and let them compete in one design. We can answer the question in this study with a clear data pattern that function is much stronger than history. In this way, the pieces of findings in previous studies might be organized together to open out a more structured blueprint in this domain.

Consider the internal cognitive processes of artifact concept categorization. The interaction pattern of function and history in this study suggests the mediating step of artifact categorization is activation of an object's function. Namely, function is the mediator between object's history and the final naming response. This "path" implication explained Gelman and Bloom's finding. Why were more objects created with intent named as artifact than objects with the same appearance but formed accidentally? The reason could be that "being created with intent" history in this condition activated representation of object's function in subject's mind. Based on the above reasoning, the utility-based view further considers the activation of object's function as the common mediator for many other single factors on artifact categorization (Figure 3).

Considering the neural correlates with artifact concepts processing, more theoretical implications are in place. Using object property production task with fMRI technique,
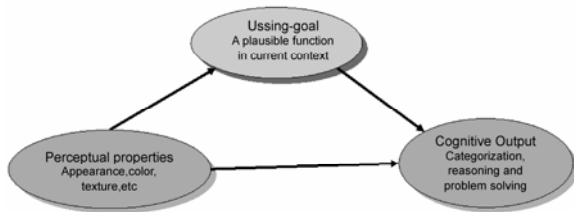
Figure 3   Utility-based model of artifact concepts processing.

researchers found left posterior middle temporal gyrus (pMTG) centered area has activation increase correlated with retrieval of concrete object concept related action (e.g. "pull" and wagon) [24,25]. Together with findings in our study, it is likely that the left pMTG will be activated when each of the single factors makes effect on artifact concept processing.

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