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Tautological formal explanations are satisfactory regardless of prior knowledge

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Abstract

Formal explanations are not tautological per se and do have explanatory power, although circular explanations can mimic them by emulating their form. (e.g., "This atom possesses an electric charge because it is an ion."). We explored the possibility of enhancing the capacity to detect circular formal explanations by pre-activating participants' prior knowledge of definitions for relevant terms. In Experiment 1, we posed questions about definitions (e.g., What is the best definition for "ion?") immediately before asking participants to evaluate the satisfactoriness of the explanation. In Experiments 2, we directly provided definitions of the terms. Across both experiments, participants consistently rating such explanations as more satisfactory compared to explicitly circular explanations (e.g., "This atom possesses an electric charge because it is an electrically charged atom"). Furthermore, Experiment 1 demonstrated that the effect is not dependent on individuals' ability to select the correct definition of a term.

Keywords: explanation, circular explanations, tautology, formal explanations, prior knowledge

Introduction

Explanations serve the purpose of assimilating new information and generalizations (Lombrozo, 2006), highlighting potentially useful details for future predictions (Lombrozo & Carey, 2006), or forming normative expectations (Foster-Hanson & Lombrozo, 2022). That is why tautological (circular) explanations are known to be ineffective as they don't introduce new information; instead, they just paraphrase the explanandum (Keil, 2006). Although individuals learn to distinguish circular explanations early on (Corriveau & Kurkul, 2014), many factors can enhance the perceived quality of circular explanations (e.g. Bulut et al., 2022). Some argue that circular and tautological explanations exist even in scientific domains like psychology and neuroscience (Hahn, 2011; Hommel, 2020). Recognizing these complexities, it's crucial to explore factors influencing the satisfaction of tautological and uninformative explanations across various domains.

In a sense, the intermediate position between circular and “proper” explanations is occupied by formal explanations, which can also be found in science and everyday life. Formal explanations are statements that assert that a certain property is inherent in an object only because that object belongs to a certain category (e.g. "It flies because it is a bird"). It is known that formal explanations help to represent a concrete object as a representative of a kind, emphasizing that certain properties of an object are "principled", i.e. should be expected "by default" (Prasada & Dillingham, 2009; Haward et al., 2018). Considering this, there is a point of view according to which formal explanations are an independent and legitimate way to explain reality, on a par with other types of explanations such as mechanistic explanations or teleological explanations (Prasada, 2017). Indeed, some works show that formal explanations are more satisfactory than circular explanations (Giffin et al., 2017; Rivera et al., 2023). However, some alternative interpretations points out that such explanations are uninformative (and close to tautologies), and therefore their satisfactoriness must arise from some non-obvious functions. For example, Hemmatian and Sloman (2018) show that completely uninformative formal explanations can serve as pointers to additional knowledge that potentially exists in the community, which is why the categorical label used for an explanation must be conventional. Gelman et al. (2018) argue that formal explanations can be satisfying because they point to a hidden internal cause that is not yet known but can be explored. Spaulding (2023) also hypothesizes that formal explanations are implicitly causal, at least when they are satisfactory. Aslanov et al. (2022) showed, that at least in some cases formal explanations help to categorize an object as a member of a superordinate category, and thus they point to prior knowledge that should be used to supplement information about a particular phenomenon.

Thus, what is known about formal explanations is that they can be quite satisfactory, but their autonomous informativeness may be questionable. Indeed, the satisfactoriness of an explanation does not mean that it is informative or useful for learning (Liquin & Lombrozo, 2022). A recent paper by Rivera et al. (2023) demonstrates that formal explanations can actually be more satisfactory than tautological explanations. This seems to provide strong evidence in favor of formal explanations potentially having more explanatory power than explicit tautologies. However, it is important to note that in their experiments the formal explanations were not tautological, e.g “That flies because it is a bird” (Rivera et al., 2023, Experiment 1) is not a tautology, because “being able to fly” and “being a bird” do not mean the same thing. Hence, this paper compared non-tautological formal explanations against obviously tautological explanations. However, can we claim that formal explanations retain their advantage if we make them intentionally tautological?

In Aslanov & Guerra (2023), a set of formal explanations was designed to make them tautological. For instance, “The

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famous archeologist Heinrich Schliemann could speak at least 15 languages, because he was a polyglot" is a tautological formal explanation since the term "polyglot" literally means any person who speaks many languages. If you know the meaning of the term "polyglot," you don't need to read the explanation to learn that Schliemann was a polyglot. You understand it automatically when you are told that Schliemann spoke many languages, because "polyglot" is just a label for a more convenient signifier of a feature you already know. This cannot be said for explanations like "That flies because it is a bird", because the categorical label does not immediately stand for the entire set of objects possessing that feature, hence such explanations are formal but not tautological.

According to Aslanov & Guerra (2023) findings, people rate circular (tautological) formal explanations as more satisfactory than explicit tautologies, but as less satisfactory than proper scientific explanations. Thus, it can hardly be said that such formal explanations always serve as a substitute competitor for other kinds of explanations; but it is indeed possible to greatly increase the satisfactoriness of a circular explanation simply by paraphrasing the explanandum in a particular way (e.g., " This atom possesses an electric charge because it is an ion " instead of "This atom possesses an electric charge because it is an electrically charged atom "). At the same time, the results of this work showed that the satisfactoriness of tautological formal explanations did not depend on whether participants knew the definition of the term (e.g., "polyglot"). This led to the assumption that participants used heuristics when evaluating explanations, considering not their meaning but their form.

Current study

Arguably, while formal explanations do have explanatory power, circular explanations also seem more satisfactory when presented as formal explanations; however, it is still not clear to what extent this effect is independent of prior knowledge. Since in Aslanov & Guerra (2023) the knowledge test was conducted already after evaluating the explanations, it is possible that the participants simply did not use their prior knowledge to analyze the explanations, relying on their natural soundness. Hence, it is still necessary to investigate if people can spot circularity hidden in formal explanations if the relevant prior knowledge is pre-activated. First of all, it will outline the limits of our ability to notice circular explanations and point out possible errors in the explanations people produce and select. Secondly, it will contribute to understanding the nature of formal explanations themselves. If formal explanations can remain satisfactory without requiring precise prior knowledge from the participants, it would suggest that their satisfactoriness doesn't always hinge on the representation of principled features (Prasada, 2017). Indeed, in the "That flies because it is X" explanation knowledge of the X is necessary - otherwise, how would we understand that the relevant feature is principled for the category X?

Instead, their satisfactoriness may be largely influenced by various "secondary benefits" associated with such explanations (e.g., Gelman et al., 2018; Hemmatian & Sloman, 2018; Spaulding, 2023), which manifest themselves in not communicating new explanatory information but rather creating the impression that such information can be found, or building normative expectations rather than deepening understanding.

Experiment 1

Participants

58 Chilean students were recruited through advertisements on Facebook (M = 22.9, SD = 2.9 years; 36 women, 17 men, 2 non-binary persons). They read and signed an informed consent. The reward for participation was 4000 Chilean pesos (around 5 USD).

Materials and design

We utilized materials from Aslanov & Guerra (2023), comprising 24 items distributed across four domains (Biology, Chemistry, Social Sciences, and Linguistics), with each domain containing six items. The experiment included three conditions: explicit tautologies ("control" condition), implicit tautologies (tautological formal explanations, "label" condition), and proper explanations ("explanation" condition). Each item had three versions corresponding to one of the conditions (see Table 1). Two fillers per domain (one for "label" and one for "explanation" conditions) were included, featuring clearly incorrect statements. The first part of the materials included 32 explanations (24 items and 8 fillers).

The second part comprised a multiple-choice questionnaire testing participants' understanding of the concepts used in the explanations. Participants were asked to select the correct definition for each term from three options. A Latin square experimental design was employed, incorporating within-subject and within-items factors for explanation type with three levels, and a within-subject between-item factor with two levels (known vs. unknown), derived from the multiple-choice questionnaire at the item level.

This experiment was preregistered (https://osf.io/cr3p7).

Table 1: Examples of experimental materials (Chemistry domain)

Condition	Item
Label	This atom possesses an electric charge because it is an *ion*.
Explanation	This atom possesses an electric charge because the number of electrons in its composition exceeds the number of protons.
Control	This atom possesses an electric charge because it is an electrically charged atom.

Procedure

Participants were randomly assigned to one of three experimental lists. They were tasked with evaluating explanations for various phenomena. Before each explanation, participants selected the best definition for a term. Definitions and explanations pertained to a single item. For instance, participants first chose one of three definitions (e.g., for "carcinogen") and then assessed an item in one of three conditions (e.g., "Alcohol promotes cancerous tumor formation as it is a carcinogen"). Evaluation involved rating the satisfactoriness of each explanations on a scale from 1 to 7. Questions were presented in pairs on separate screens: a definition question followed by an explanation question (see Figure 1). The order of questions within pairs was consistent, but pair order was randomized. The experiment was conducted online using the Open Lab platform (Shevchenko, 2022) and was built in lab.js editor (Henninger et al., 2020).

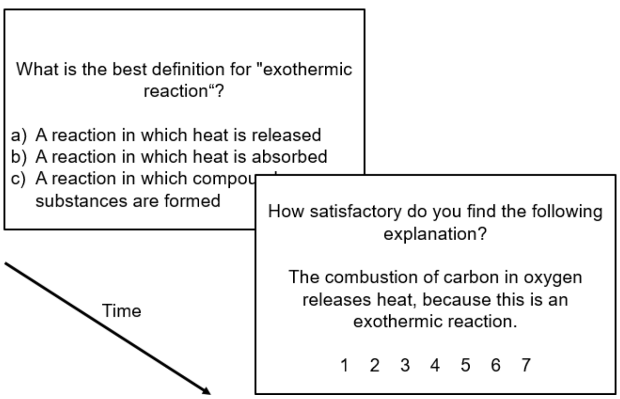

Figure 1. Schematic representation of a trial in Experiment 1

Data analysis

In theory, participants could rate 8 trials as 1 (control condition) and another 8 as 7 (explanation condition) based on instructions and materials. The label condition's expected response pattern was less predictable but hypothesized to fall mid-scale. Hence, prior to analysis, we checked data integrity by examining response frequencies for each participant, identifying systematic patterns indicating inattention. We established that if a participant provided 14 or more responses rated as 7, they were excluded from the sample. We excluded 12 participants based on this criterion. Among the remaining 46, accuracy ranged from 45% to 100%. Before conducting inferential analysis on independent variables, we assessed if our statistical power ($\geq$ 0.8) was sufficient for testing hypotheses. This involved 1,000 simulations using parameters from real data, with two separate scenarios: one with 46 participants and 24 items, and another with 100 participants and 24 items. Results indicated adequate power for the initial hypothesis but insufficient for subsequent ones with 46 participants. Specifically, power for label vs. explanation conditions was 0.92, for label vs. control conditions was 0.84, and only 0.051 for label conditions with and without concept knowledge. In a second simulation with 100 participants, power increased to 0.069 and 0.99 for the first two contrasts, but the sample size remained at 46 participants due to preregistration limits.

We employed a mixed-effects regression approach for statistical analysis, utilizing the lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017) packages within R (R Core Team, 2023). The regression included fixed effects for the experimental condition (type of explanation), participant knowledge, and their interaction. We placed particular emphasis on the label condition in our analysis, designating it as an intercept. To assess participant knowledge, we utilized a sum contrast, allowing us to differentiate responses based on whether the definition was known or unknown. The random structure of our model involved random intercepts for both participants and items. The model considered random slopes for the knowledge factor, type of explanation, and their interaction at the participant level. However, at the item level, only the type of explanation was treated as a random slope, recognizing that knowledge varied among items.

Results and discussion

The results of Experiment 1 indicate findings from the linear mixed-effect regression analysis. The label condition significantly differed from the explanation conditions (Estimate = 0.624, se = 0.211, t-value = 2.953, $p < 0.01$), and from the control condition (Estimate = -0.563, se = 0.242, t-value = -2.32, $p < 0.05$). No distinctions were observed for the label condition based on participants' knowledge (Estimate = 0.159, se = 0.108, t-value = 21.853, $p < 0.000$). The results represented in Figure 2, align with our hypothesis: the control condition received the lowest ratings, the explanation condition the highest, and the label condition's ratings fell in between.

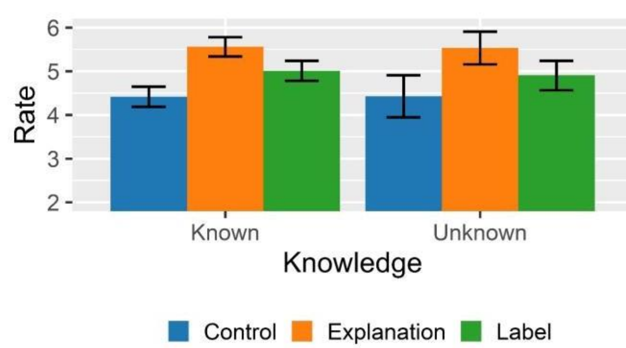

Figure 2. Mean rate as a function of experimental condition (Control, Explanation and Label) and Knowledge (Known vs. Unknown) in Experiment 1. Error bars represent 95% confidence intervals adjusted for within-subject designs.

In Experiment 1, we found that participants consistently preferred tautological formal explanations over explicit tautologies even when we pre-activated their knowledge before evaluations. These results replicate earlier findings (Aslanov & Guerra, 2023) and emphasize that activating prior knowledge about the concept does not eliminate the preference for tautological formal explanations.

However, we can also speculate that in choosing definitions, participants did not always rely on their actual knowledge of the definitions, and in some cases interpreted their choices as mere guesses. Therefore, in Experiment 2, we used a stronger manipulation by directly communicating the correct definition to participants before they evaluated the explanation.

Experiment 2

Participants

31 Chilean students (M = 22.1, SD = 4.9 years; 19 women, 11 men, 1 person chose not to specify gender). They read and signed an informed consent. The reward for participation was 4000 Chilean pesos (around 5 USD).

Materials, design, procedure, and data analysis

Using the same materials as in Experiment 1, we opted for a different approach directly providing the participants with correct definitions. We employed a Latin square experimental design with a within-subject and within-items factor (explanation type) featuring three levels. Similar to Experiment 1, each participant was assigned to one of three experimental lists, evaluating explanations in different conditions. Definitions for relevant labels were presented alongside questions about the satisfactoriness of explanations for all items in label condition on the same screen (Figure 3). The overall procedure mirrored Experiment 1. The data analysis procedure was the same with the exception that only experimental conditions were contrasted, as there was no known vs. unknown distinction. Only three participants were excluded based on the same criteria for response frequency.

This experiment was preregistered (https://osf.io/cr3p7).

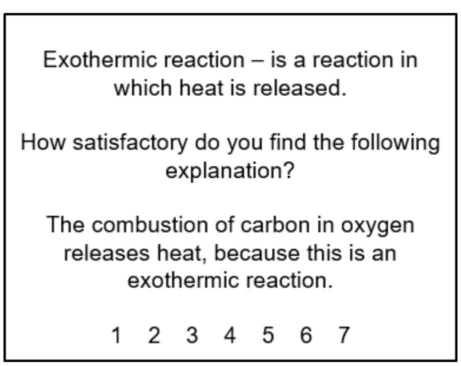

Figure 3. Schematic representation of a trial in Experiment 2

Results and discussion

Similar to Experiment 1, we conducted two simulations using our original sample number (n=28) and a hypothetical one with 100 participants. Both simulations showed a statistical power of 1. The results of the linear mixed-effect regression show statistically significant differences between label and explanation (Estimate = 0.811, se = 0.249, t-value = 3.254, $p < 0.01$) and label and control (Estimate = -0.984, se = 0.244, t-value = -4.031, $p < 0.001$) conditions. Figure 4 displays the pattern of results observed in Experiment 2.

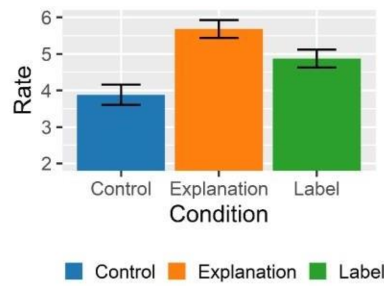

Figure 4. Mean rate as a function of experimental condition (Control, Explanation and Label) in Experiment 2. Error bars represent 95% confidence intervals adjusted for within-subject designs.

Thus, Experiment 2 confirms our previous results and shows that tautological formal explanations are more satisfactory than explicit tautologies regardless of prior knowledge.

General Discussion

While tautologies may occasionally serve effective communication by invoking shared knowledge, the prevailing view is that they are generally considered uninformative (Baum et al., 2008; Corriveau & Kurkul, 2014; Sands et al., 2023). The inherent contradiction between circularity and the fundamental functions of explanation, such as highlighting information for future predictions, makes tautologies unsatisfactory (Lombrozo, 2006; Lombrozo & Carey, 2006).

In our study, we compared explicit tautological explanations and implicit ones that take the appearance of formal explanations. In line with our previous findings (Aslanov & Guerra, 2023), participants rated tautological formal explanations as more satisfactory compared to explicit tautologies, but less satisfactory compared to proper scientific explanations. Current evidence shows that even preactivation of prior knowledge does not help participants detect hidden tautologies.

Experiment 1 shows that the satisfactoriness of formal explanations is either independent of whether participants know the correct definition of the categorical label, or the effect of this knowledge, if it exists, is very small. Although we did not propose hypotheses within the framework of kind representation theory (Prasada, 2017), we believe that these data may be of interest in its context. If the satisfactoriness of formal explanations is based exclusively on their ability to draw connections to principle features of a kind, then we should have expected that adequate categorical knowledge would provide advantages for such explanations. Indeed, people need to know what a “polyglot” is in order to understand what features of that category are principled. But according to our results, it was not the case, hence the satisfactoriness of formal explanations can be a function of several important factors.

Thus, our results provoke reflection on the nature of formal explanations and their reliance on cognitive "secondary benefits." The unexpected satisfaction with tautological formal explanations, irrespective of participants' prior knowledge, suggests that their persuasiveness may be rooted in factors beyond categorical knowledge representation. This raises questions about the role of context, heuristics, and cognitive mechanisms in shaping individuals' perception of tautological formal explanations.

Experiments 2 replicated the pattern observed in Experiment 1, highlighting the robustness of our findings. This is also consistent with data from Hemmatian et al. (submitted) who show that even knowledge active in the memory is unable to undermine the seductive allure of formal explanations. While proper explanations consistently garnered higher scores, the intriguing additional satisfaction with tautological formal explanations warrants further exploration. We propose that future research should delve into individual differences, considering factors such as need for cognition (Minahan & Siedlecki, 2016), and explore subtypes of proper explanations to pinpoint the characteristics that make tautological formal explanations distinctive in terms of satisfactoriness.

It is also worth mentioning that proper explanations consistently received higher scores in both experiments. This implies that tautological formal explanations were not universally perceived as 'complete' by participants. However, the challenge lies in explaining the "additional" satisfaction compared to explicit tautologies. Our earlier hypothesis suggested that individuals interpreting tautological formal explanations might either fail to activate prior knowledge or they are susceptible to heuristics, relying on a "false" sense of satisfaction. This study reveals that the satisfactoriness of such explanations remains independent of prior knowledge or its activation, rendering tautological formal explanations illusorily satisfactory for all individuals, regardless of their ability to separate the hidden tautology. Consequently, it seems that the logical structure of a formal explanation itself plays a much larger role than previously thought. We can assume that, in this case, participants evaluate the satisfactoriness of explanations based on an intuitive system (System 1) grounded in heuristics, as shown for several other heuristics in evaluating explanations (Hemmatian & Sloman, 2020).

Finally, several limitations of our study should be pointed out. First of all, since the materials were not tested among experts and were generated based on dictionary definitions and open sources, it may be necessary to assess whether tautological formal explanations are indeed tautologies from the experts' point of view to avoid inaccuracies in the wording. Since the design of the experiments did not allow the use of simple and well-known categories such as "cat", "stone" and so on, some categorical labels have the potential to have too broad a meaning, so their careful use may need supervision by experts in the relevant disciplines.

Second, as there is evidence that individual differences can play a large role in the evaluation of formal explanations (see Hemmatian et al., submitted), the study of such differences may be of interest. The small sample size in the present experiments does not allow for this, and future experiments should increase the number of participants to explore possible predictors.

Conclusion

In summary, our study unveils a paradoxical observation: tautological formal explanations, despite their inherent circularity, consistently garner higher satisfaction ratings compared to explicit tautologies. This phenomenon persists regardless of participants' prior knowledge or the provision of direct definitions during evaluation. These findings underscore the key role that the formal structure of an explanation plays in shaping its perceived validity.

The allure of formal explanations extends beyond factual content, with formal structures exerting a significant influence on perceived satisfactoriness. This discovery holds profound implications for our comprehension of how individuals process information and assess the validity of arguments and explanations.

To delve deeper into this cognitive intricacy, future research should scrutinize the underlying mechanisms that contribute to the heightened satisfaction with formal explanations over their tautological counterparts. Investigating individual differences, such as the need for cognition, and exploring various types of explanations (causal, functional, teleological, etc.) will enrich our understanding of the intricate interplay between form and content in human cognition and communication.

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