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Similarities Between Objects in Analogies Framed by Schema-Governed Categories

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Abstract

The present study was aimed at assessing the effect of object similarities on participants' evaluations of analogical quality. Results from an experimental condition in which the relations involved in the compared situations were explicitly highlighted, showed that general object similarities (membership to same category) positively affected the evaluations of analogical quality. In contrast, no such effect was found under another experimental condition in which the analogical comparisons between the same situations were framed by a schema-governed category. An analysis of participants' justifications revealed that the object similarities that were taken into account under this second condition were related to central dimensions of the schema-governed category that was used to frame the analogies. We explain these findings within the category assignment approach developed by Minervino et al., and discuss the implications of this alternative perspective of analogical reasoning for the role of similarities between entities playing several thematic roles.

Keywords: analogy; schema-governed category; semantic similarity.

Introduction

Drawing an analogy consists in recognizing that two situations are comparable because they share a common relational structure despite their superficial differences. Frequently, the purpose of analogical comparisons is to transfer knowledge from one of those situations (the *base analog*) to the other (the *target analog*) to enhance its comprehension (Gentner, 1983; Holyoak, 1984).

The structure-mapping theory (Gentner, 1983, 1989; Gentner & Markman, 1997) and the multiconstraint theory (Holyoak & Thagard, 1989; Hummel & Holyoak, 1997) have dominated the discussion about analogical reasoning since the 1980s. Due to the commonalities between these two theories we will refer to them as the *standard approach.* According to this approach, analogical reasoning involves, among other subprocesses, a mapping between base and target elements, and an evaluation of the quality of the analogy. Both theories agree in that the quality of a match will be considered higher or lower to the extent that the alignment satisfies the structural constraints of one-to-one mapping and parallel connectivity (Gentner, 1989; Holyoak & Thagard, 1989). Nevertheless, the mentioned theories differ with respect to the role of semantics in the evaluation of an analogy. Structure-mapping theory posits that relational similarity is the only factor that counts when evaluating an analogy, with object similarities playing no role at all (Gentner, 1983, 1989). On the other hand, the multiconstraint theory contends that semantic similarity between objects is also taken into account during quality evaluations (Holyoak, 1984; Holyoak & Thagard, 1989). The mechanisms proposed by these theories for estimating semantic similarity tend to resort to general knowledge like the one represented in networks (Minervino, Oberholzer, & Trench, 2013). The scarce available evidence (Gentner, Ratterman & Forbus, 1993; Gentner & Kurtz, 2006) is consistent with structure mapping theory: it shows a clear relational focus, with only a minimal influence of object similarities on judgments of analogical relatedness.

To illustrate the implications of the relational focus in a more concrete way, suppose that people were faced with a task of rating the quality of the analogies that hold between the top and bottom scenes of Figure 1. Dismissing the similarity between the objects *computer mouse* and *laptop* as two members of the entity category *computer equipment*, and the semantic differences between a *computer mouse* and a *pair of socks* (two objects lacking a common entity category), people would probably rate Facts A and B as equally analogous to the Key fact, because they are three cases of *giving*, and what counts in quality evaluations are relational similarities.

In the present research we present an alternative approach to standard theories of analogy, with implications on the role of object similarities during analogical comparisons. While we tend to agree with the multiconstraint theory in granting a role to object similarities, we posit that the computation of object properties that takes place during

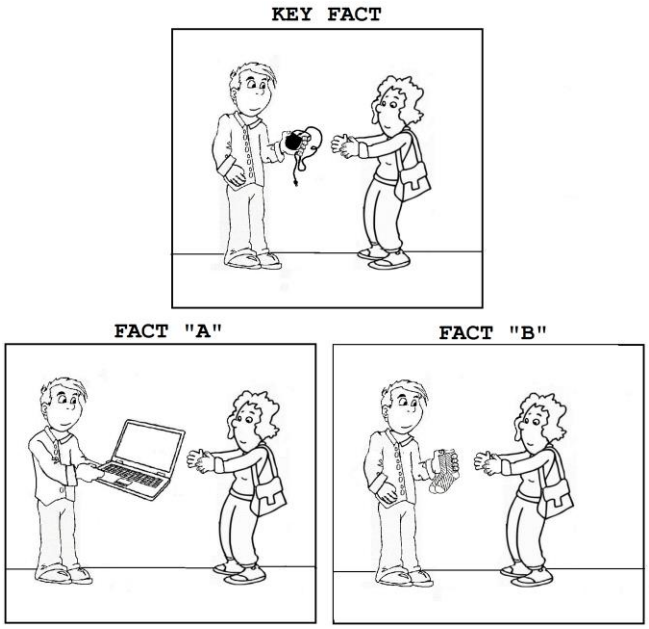

Figure 1. One example of an analogy in which the base (key) and target situations (A and B) have similar relations, but hold general differences among their objects.

evaluations of analogical quality does not involve assessing the proximity between base and a target objects within a hierarchically organized network of concepts. The proposals of the standard theories may be suitable for certain kind of analogies like those used by Gentner and Kurtz (2006). For example, the analogical relatedness between *John bought the candy* and *John took the lollipop* could be decided considering the similarity between *buy* and *take* in isolation. However, standard proposals might not be appropriate in those cases in which the interaction between the propositional elements composing the analogs gives rise to exemplars of a *schema-governed relational category*.

Exemplars of a given schema-governed category like *aggression* share a common schematic structure (Gentner & Kurtz, 2005; Goldwater, Markman & Stilwell, 2011; Markman & Stilwell, 2001), which could be instantiated by a wide range of exemplars, like *the preschooler threw a pen to his partner, the soccer player broke a leg to his rival* and *the girl sank her brother's head into a bucket*. The alternative approach of analogical reasoning that we are presenting here supposes that two situations would be considered analogous if they could be assigned to a common schema-governed category (Minervino et al., 2013; Oberholzer, Trench & Minervino, 2011). Frequently, in real communicational scenarios a certain schema-governed category is explicitly introduced previous to the acts of comparing and evaluating the analogability of two situations. For example, a man could tell to a friend: "Hey, I have seen *cheating-like behaviors* in my wife*:* The other day she hid her cellphone from me". To express comprehension, the friend could reply by telling an analogous situation: "The same thing happened to me! My wife hid her credit card records from me". On the other hand, in absence of a framing schema-governed category, the comparison could be alternatively focused in the lower-level actions implied in the compared situations (e.g., the two situations could be considered analogous just as cases of *hide*). While standard theories of analogies seem appropriate to explain the lower-level type of analogical processing, the assignment approach is focused on a higher-level type of analogical reasoning guided by schema-governed categories.

With respect to the evaluation of analogies, the assignment approach posits that relational similarity is not necessary nor sufficient. Note in above examples that *the preschooler threw a pen to his partner* and *the soccer player broke a leg to his rival* could be considered analogous as cases of *aggression* despite not sharing similar relations (i.e., *throw* is not semantically similar to *brake*). Furthermore, *hiding the cellphone from the husband* could be considered as not analogous to *hiding the pie from the husband* besides sharing the relation *hide*, due to the fact that they could not be assigned to a common schema-governed category (e.g., *cheating-like behavior*).

With respect to the role of objects in analogical relatedness judgments, the assignment approach posits that object similarities are taken into account to the extent that they could modify the value that the facts under comparison displayed on one *dimension* of the schema-governed category to which the analogs belong. For example, in Figure 1, the assignment approach predicts that if the comparison is framed by the schema-governed category *awarding*, people would rate Fact B as more analogous to the Key fact than Fact A because of the closeness of those first two situations in the value that they exhibit along the *importance* of the awarding. Object properties that count in evaluating the analogical relatedness of the Key fact with respect to Facts A and B are those related to the importance of the awarding, for example, the *price* of each object. Thus, as a *pair of socks* has a similar price than a *computer mouse*, the quality of the analogy between the Key fact and the Fact B would be better rated than the quality of the analogy between the Key fact and the Fact A, in which the award consists of a more expensive laptop. This treatment of semantics differs from the one given by standard theories of analogy, because it does not consider similarities and differences between objects like those provided by general knowledge networks (e.g., the similarity between a computer mouse and a laptop as members of the category *computer equipment*). Instead, the mechanism proposed by the assignment´s approach for computing semantic similarities takes into account those aspects of objects that become relevant as an effect of the schema-governed category that is framing the comparison. For example, the *price* of the objects becomes relevant because it affects the values that the compared situations exhibit in the dimension of *importance* of the awarding.

The objective of this study was to assess whether the object similarities in properties that affect the value of the compared situations in a certain dimension of the framing

schema-governed category have an effect on quality evaluations of the analogy, as opposed to general object similarities, operationalized as membership to same category[1]. With this purpose, we designed an experiment in which two groups of participants received triplet of images like the ones displayed in Figure 1, which were framed either by a relation or by a schema-governed category. While one of the target objects maintained general similarities with respect to the base object in terms of their membership to a same category (e.g., computer mouse and laptop), the object of the second target did not hold general similarities with the base object (e.g., computer mouse and pair of socks). Nevertheless, the second target object could be considered more similar than the first one with respect to the base object in terms of a property (e.g., the price of the awards) that becomes relevant under a schema-governed category framing (e.g., awarding). In light of existing evidence regarding the negligible role of objects during standard analogical comparisons, we predicted that participants whose analogies were framed by the central relation (i.e., action represented by a verb) of the compared situations would rate both targets as being equally analogous to the base situation. However, the above considerations about the likely role of schema-governed categories during analogical comparisons led us to predict that framing the analogies under a common schema-governed category would lead participants to give higher scores to target analogs whose objects were not taxonomically related to those of the base situation, but which allowed a matching with respect to the base situation in terms of their value along a relevant dimension of the framing category.

Method

Participants and design

Forty students of Psychology at the University of Comahue (mean age = 21.4 years, *SD* = 2.08) volunteered to participate in the experiment, and were randomly assigned to one of two experimental conditions. The experiment has a 2x2 repeated measures design, with the independent variable *framing of the analogies* (same relation vs. same schema-governed category) as a between subject factor, and *general object similarity between base and target* (presence vs. absence), as a within subject factor. The dependent variable was the *quality evaluation of analogies*.

Procedure

Participants of the two conditions of the experiment received a brief instructional text. It anticipated that they would receive several sets of three drawings in which a first scene (Key fact) would be followed by two *analogous* scenes (Fact A and B, respectively), that is, by two "situations that are analogous to the first one in essential aspects, despite being different in others". Participants were told that they should consider whether the Fact A or B seems to them as more analogous to the Key fact, or if both could be seen as equally analogous to the Key fact. The instructional material also anticipated that each set of scenes would be preceded by a brief description of the actions involved in the three drawings of the set, and followed by a prompt to provide ratings for the extent to which Facts A and B could be considered analogous to the Key fact, and a verbal justification for their scoring. After reading these instructions, participants were provided with a set of practice materials. They did not receive any feedback about the content of their responses during this practice or during the experiment itself, but they did receive feedback about how to carry out the tasks. Upon reading the instructions and solving the practice trial on a computer display, all of the participants were asked to analyze each of the subsequent triplets of visual scenes at their own pace, typing their responses into the spaces provided in the Word file, and advancing to the next screen once they had finished the tasks of each set. Participants of both groups received six critical sets of scenes interleaved by six filler sets designed to prevent participants from grasping the response pattern that was favored by the manipulation in each condition. Each trial, which appeared on a different screen of the computer file, displayed a first visual scene (the base analog, named *Key fact*) on the uppermost section of the screen, followed by two alternative visual scenes (the targets, named respectively *Fact A* and *Fact B*) placed one next to the other (see Figure 1). Participants in the *similar relation* framing condition (n = 20) received all triplets preceded by a brief statement stressing the verb that applied across the scenes (e.g., "These are three instances of *giving*"). In contrast, participants in the *similar schema-governed category* framing condition (n = 20) received all triplets preceded by a schema-governed category that could be applied to all scenes (e.g., "These are three instances of *awardings*").

First task: Evaluation of the quality of the analogies
Using a 5-point Likert scale (1 = barely analogous; 5 = completely analogous), participants were asked to rate (1) the extent to which the Key fact could be considered analogous to the Fact A, and (2) the extent to which the Key fact could be considered analogous to the Fact B.

Second task: Verbal justifications of the quality scores
Participants were encouraged to write down a verbal justification for the previously assigned scores. For this task, they were presented with three possible kinds of unfulfilled answers followed by a blank space: (1a) “I have assigned a higher score to the comparison between *Key fact/Fact A* than to the comparison between *Key fact/Fact B* because…”, (1b) “I have assigned a higher score to the comparison between *Key fact/Fact B* than to the comparison between *Key fact/Fact A* because…” or (1c) “I have assigned the same scores to both comparisons because…”.

[1] Traditionally, general object similarity was manipulated as the membership of two objects to a same taxonomic category (e.g., Gentner & Kurtz, 2006). However, general object similarities could also refer to other commonalities between objects taken in isolation, like, for example, intrinsic and functional properties.

Materials

Six critical sets of drawings were built, each one comprising a base situation and two target situations (see Table 1). The characters and the actions they were performing were identical across the three scenes of each set, and could be framed either as instantiations of a common relation (e.g., two cases of *giving*) or as instantiations of a common schema-governed category (e.g., two instances of *awarding*). In contrast to the characters and their actions, which were kept constant across the three scenes of each set, the objects involved in such actions were varied. The object of one of the targets was similar in general aspects to its corresponding base object (e.g., a *computer mouse* and a *laptop* are two exemplars of the entity category *computer equipment*), but could not be equated to the base object along a central dimension of the schema-governed category that could be potentially applied to both scenes (e.g., if the base and the first target were framed under the schema-governed category *awarding*, then the importance of winning a *laptop* is not comparable to that of winning a *computer mouse*). The objects involved in the second target were chosen to display the opposite pattern: they did not maintain general object similarities with respect to the base object, but could nevertheless be equated to the base object in certain properties that become relevant under a schema-governed category framing that could be potentially applied to both scenes (e.g., while *computer mouse* and a *pair of socks* are not similar, they constitute awards of comparable importance). The order of presentation of the critical sets and the right/left position of their corresponding targets were counterbalanced.

Table 1: Experimental materials

Set #	Framing SGC/ Relation	Description of the pictorial situations
1	Physical exercise/ Relocate	A man is relocating **big desks (BA)/ tiny stools (TA1)/ truck wheels (TA2)** inside a room
2	Bragging/ Point	A man is pointing a **sports car (BA)/ bicycle (TA1)/big house (TA2)** to a woman
3	Smuggling/ Load	A man is loading **led TV´s (BA)/ fans (TA1)/ paintings (TA2)** into a truck
4	Celebration/ Open	A woman is opening a **bottle of champagne (BA)/ soda (TA1) / cake box (TA2)**
5	Awarding/ Give	A man is giving a **computer mouse (BA) / laptop (TA1)/ pair of socks (TA2)** to a woman
6	Electricity consumption/ Plug	A woman is plugging in a **table lamp (BA)/ floodlight (TA1) / radio (TA2)**

Note. SGC: Schema-governed Category; BA: Base Analog; TA1: Target Analog 1; TA2: Target Analog 2.

Results

A 2x2 ANOVA with Framing condition (same relation vs same schema governed category) as between-subjects factor and General object similarity (presence vs absence) as within-subjects factor was conducted to assess how these variables impacted the perceived quality of analogies. Main effects were neither found for condition, $F(1,38) = 1.01$, $MSe = 0.76$, $p = .31$, nor for general object similarity, $F(1,38) = 3.93$, $MSe = 0.90$, $p = .055$). However, there was a significant interaction between the framing condition and general object similarity, $F(1,38) = 146.32$, $MSe = 33.58$, $p < .01$ (see Figure 2). Post-hoc Tukey HSD tests revealed that in the same relation condition the ratings of the quality of the analogy were significantly higher for items with general object similarity ($M = 3.77$, $SD = 0.697$) than for items without general object similarity ($M = 2.68$, $SD = 0.739$, $p < .01$). Against structure mapping, these results showed that general object similarities affected the perceived quality of analogies framed by a relation. The opposite pattern of results was observed across the same schema-governed framing condition, in which the items without general object similarity but with similar dimensional value obtained significantly higher ratings ($M = 3.78$, $SD = 0.549$) than items with general object similarities ($M = 2.27$, $SD = 0.797$, $p < .01$).

A further qualitative analysis of the verbal justifications was performed in order to explore the principles underlying the evaluations of the quality of analogies. Two independent judges, both cognitive psychologists, were instructed to classify the principles applied by participants in their justifications into one of three categories: related to general object similarities, related to a verb, or related to a dimension of the framing schema-governed category. Judges should classify the principle as *related to general object similarities* if participants´ justifications referred object similarities and differences that were not related to the verb or to the schema-governed category used to frame each triplet of images (i.e., that could be identified and conceptualized independently of the specific framing verb or schema-governed category). Judges were told that responses of this type may include similarities and differences between intrinsic properties of objects, their functions or their taxonomic membership, and were provided with examples (e.g., a computer mouse has the same *color* than a laptop). The principle should be classified as *related to a verb* if participants mentioned similarities and differences in object properties that affect dimensions of the framing relations (e.g., a computer mouse is *easier to give* than a laptop). Judges should classify the principle as *related to a dimension of the framing schema-governed category* if participants mentioned similarities and differences between object properties that are related to a dimension of the framing schema-governed category (e.g., receiving a laptop is a *more important awarding* compared to receiving a computer mouse). Judges agreed in 86% of the cases, and cases of disagreement were resolved by discussion. This qualitative analysis showed that in the

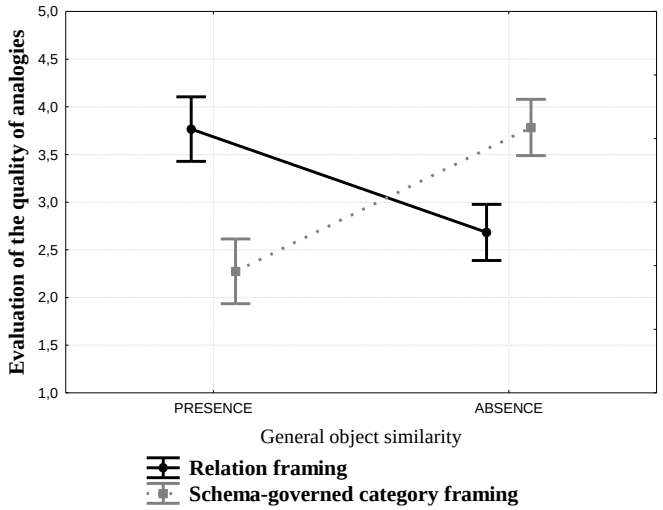

Figure 2. Interaction between framing condition and general object similarity in quality evaluations.

condition framed by a relation, participants' justifications followed a principle related to general object similarities in 75% of the cases, and a principle based on dimensions of the verbs in 25% of the cases. In contrast, in the condition framed by a schema-governed category, participants used the principle related to general object similarities only in 7% of the cases, whereas in the remaining 93% of the cases they applied the principle related to a dimension of the framing schema-governed category. None of the responses of the schema-governed framing condition referred to a principle related to the verb. This analysis provides complementary evidence that general object similarities are taken into account in the same relation framing condition, but had almost no influence over quality evaluations of the schema-governed framing condition. Moreover, justifications´ analysis confirmed that object similarities that count in quality evaluations of analogies framed by a schema-governed category are those related to object properties that bear on the degree to which the facts under comparison match along a relevant dimension of the framing category.

Discussion

The present study showed that when matched objects belong to the same category, this similarity positively influences the perceived quality of a "standard" analogy (i.e., an analogy not framed by a schema-governed category). One possible explanation of the inconsistency between this finding and previous evidence (e.g., Gentner & Kurtz, 2006; Gentner et al., 1993) could be that in our study participants were asked to justify their ratings, and there is some evidence that justifying ratings of analogical relatedness can lead to poorer discrimination between superficial and structural aspects of analogies (Sieck, Quinn & Schooler, 1999). In any case, the central finding of the present study was that when an analogy is framed in terms of a schema-governed category, the object properties that matter when assessing analogical comparisons are those that affect the value of the compared situations along certain dimensions of the framing schema-governed category, as opposed to the type of object similarities considered by the standard approach.

A question that may arise from our study refers to whether the framing of analogical comparisons under schema-governed categories (as in our schema-governed condition) represents a frequent or a rare occurrence in daily real-life scenarios. An example widely discussed by the multiconstraint theory indeed suggests that schema-governed analogies are rather frequent, and that the conceptualization of similarities and differences between objects has clear implications for the generation of analogical inferences. In the context of the Vietnam/Persian Gulf analogy, Holyoak and Thagard (1995) mention that the contrast between the jungle of Vietnam and the desert sands of Kuwait was key to predicting whether the army of Saddam could be defeated by air strikes: As opposed to the aptness of the Vietnamese jungle for concealing the army, the desert sands are not of great help. As this example clearly illustrates, the comparison is framed under the schema-governed category *war*, and under this framing certain properties of the object *ground* become relevant—properties that one would not analyze in the absence of such particular framing. It is our intuition that many analogical comparisons that take place in everyday contexts are contextually framed in terms of schema-governed categories: Is the economic crisis of 2008 analogous to that of 1930?, Are the terrorist attacks perpetrated by Muslim fanatics analogous to those of radical independists of Ireland?, Is the populism led by Donald Trump analogous to the one led by Cristina Fernández de Kirchner?

The discrimination between analogies that are processed under a schema-governed category and those that are not is relevant to designing experimental materials as well as to interpret results of existing studies on analogical thinking. Just to illustrate, Figure 3 displays one of the sets of pictures employed by Markman and Gentner (1996, p. 242) to determine whether alignable differences count more than non-alignable differences during similarity judgments. If forced to decide which of the alternative target scenes is more analogous to the base situation, readers would probably choose the one on the left, as did participants of such study. As posited by the authors, what explains this preference is the fact that while the replacement of the target object by a bird represents an alignable difference in the context of the rightmost scene, such replacement represents a non alignable difference within the left scene. Alternatively, one could sensibly argue that while the left scene has to do with the physical ability of aiming at a target, the right scene represents a case of the schema-governed category *zoocide*. The processing of analogies under schema-governed categories does not always require the external provision of a suitable schema-governed category. As shown by Minervino et al. (2013), schema-governed categories could be naturally activated in reasoners by the

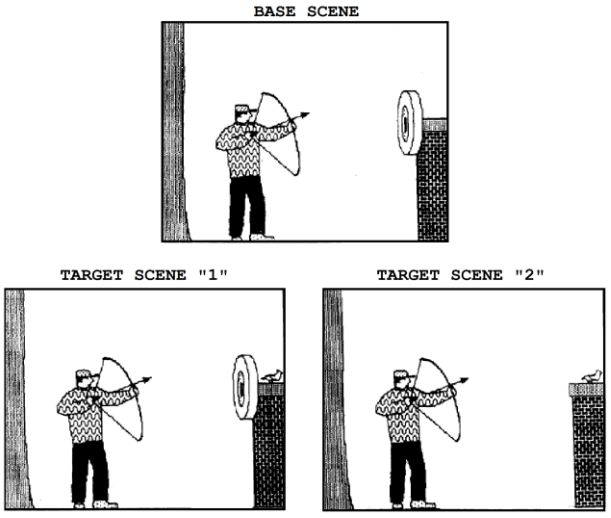

Figure 3. Sample of materials used to determine whether alignable differences or nonalignable differences count more during similarity evaluations. Adapted from "Commonalities and differences in similarity comparisons", by A.B. Markman & D. Gentner, 1996, *Memory & Cognition*, *2*, p. 242

situations themselves. In fact, during the construction of the stimuli employed in the present study we found it hard to devise situations for which the schema-governed categories that were explicitly presented in the *schema-governed category* framing condition would not be automatically evoked by participants in the *same relation* condition.

While the present study shows that a schema-governed category framing leads people to highlight object properties (e.g., *price* of the award) that are relevant to analogical quality evaluations, a question that may arise is whether just activating those properties without activating the whole schema will yield the same results. An experiment that could shed light on this would involve a comparison between the schema-governed framing condition of the present experiment and another identical condition in which the woman (i.e., the *patient* of the awarding) was replaced by a *billionaire*. While the consideration of the price of the objects under the first condition allowed participants to rate the Key fact as more analogous to the Fact A than to the Fact B, we hypothesize that under the other condition people would rate both facts A and B as almost equally analogous to the Key fact. This would evidence that in the schema-governed category framing condition people are not just taking into account object properties, but are considering the interaction between object and patient properties (e.g., object´s *price* and *richness* of the patient). Thus, it seems likely that people take into account the interaction between the fillers of every thematic-role (e.g., object, patient, agent, and instrument) and their relevant properties to judge the analogability of the compared situations. Future studies should assess the adequacy of these and other predictions that stem from the category assignment approach.

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