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Brief article

Revealing ontological commitments by magic

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ABSTRACT

Considering the appeal of different magical transformations exposes some systematic asymmetries. For example, it is more interesting to transform a vase into a rose than a rose into a vase. An experiment in which people judged how interesting they found different magic tricks showed that these asymmetries reflect the direction a transformation moves in an ontological hierarchy: transformations in the direction of animacy and intelligence are favored over the opposite. A second and third experiment demonstrated that judgments of the plausibility of machines that perform the same transformations do not show the same asymmetries, but judgments of the interestingness of such machines do. A formal argument relates this sense of interestingness to evidence for an alternative to our current physical theory, with magic tricks being a particularly pure source of such evidence. These results suggest that people's intuitions about magic tricks can reveal the ontological commitments that underlie human cognition.

What is a better magic trick, turning a glass of milk into a white dove, or turning a white dove into a glass of milk? The first trick seems intuitively more interesting, but why? It could be because transformations are evaluated based on similarity, and similarity is asymmetric (Tversky, 1977), or simply because it is more exciting to make a bird appear than a beverage. In this paper, I suggest a deeper explanation: our intuitions about magic tricks reveal the fundamental categories and conceptual structures that we use to organize our experience – what philosophers call *ontological commitments* (e.g., Ryle, 1938).

The ontology of a language or conceptual structure characterizes the set of entities that can exist and the kinds of relations that can hold between them (or, as Quine (1948) put it, "what there is"). Our ontological commitments also constrain the properties that entities are allowed to have. For example, we can say that "Water is heavy", but not "Water is sorry". Sommers (1959, 1965) argued that these "predicability" relationships can be captured in a hierarchical structure (see Fig. 1). Entities acquire applicable predicates as they move down the hierarchy, ending in animate, intelligent entities such as people. Keil (1979, 1983) explored the ontological commitments of children and adults by examining their willingness to extend predicates over entities at different locations in a hierarchy. He found that both adults and children constrained predicates in the way predicted by this account. Following critiques of this approach (Carey, 1983; Gerard & Mandler, 1983), Keil (1989) used a different method to investigate the ontological commitments of children: transformations. Children were more resistant to the possibility of surgical transformations that crossed ontological categories (e.g., an animal into a plant) than those that remained within ontological categories (e.g., an animal into another animal).

Kelly and Keil (1985) reported results that suggest ontological commitments might have an effect on the

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way that people think about magic. They studied the properties of a different class of transformations – the magical transformations that appear in myths and fairy tales. Kelly and Keil (1985) found that the transformations that appear in Ovid's *Metamorphoses* and Grimms' fairy tales tend to cover shorter distances in a predicability hierarchy than might be expected by chance. For example, it is more common for people to be transformed into animals than transformed into inanimate objects. These results were explained as the outcome of the adaptation of stories to be comprehensible by human audiences, for whom crossing many ontological boundaries would be too counter-intuitive. However, Kelly and Keil (1985) also pointed out some of the potential confounds in these results due to the fact that transformations take place in stories (for example, it is hard to maintain a narrative without a main character who is animate).

The apparent influence of ontological commitments on magical transformations in myths and fairy tales suggests that the same factor might be at work in our intuitions about the quality of magic tricks. Research at the intersection of psychology and magic has tended to focus on how theories and empirical results from psychology can be used to systematically organize the principles behind conjuring (Lamont & Wiseman, 1999; Nardi, 1984; Triplett, 1900) or on the psychological and neural basis of specific magic tricks (Cavina-Pratesi, Kuhn, Ietswaart, & Milner, 2011; Cui, Otero-Millan, Macknik, King, & Martinez-Conde, 2011; Demacheva, Ladouceur, Steinberg, Pogossova, & Raz, 2012; Kuhn, Amlani, & Rensink, 2008; Martinez-Conde & Macknik, 2008; Olson, Amlani, & Rensink, 2013; Otero-Millan, Macknik, Robbins, & Martinez-Conde, 2011; for a review and critique of some of this work, see Lamont, Henderson, & Smith, 2010). This previous research has typically explored the effects of attention and perception, rather than higher-level cognition. However, developmental research has examined the relationship between magical and causal reasoning (Chandler & Lalonde, 1994; Johnson & Harris, 1994; Phelps & Woolley, 1994; Rosengren & Hickling, 1994), and magic tricks are routinely used to investigate the ontological commitments of infants: measuring the surprise shown when objects appear and disappear has been used to study infants' expectations about the properties of objects and the nature of number (for classic examples, see Baillargeon, Spelke, & Wasserman, 1985; Wynn, 1992; Xu & Carey, 1996).

Magic tricks might thus provide a tool for exploring the ontological commitments of adults. Transforming a glass of milk into a white dove moves down the predicability hierarchy shown in Fig. 1, while the opposite transformation moves up the hierarchy. To explore the possibility that direction of movement in an ontological hierarchy might explain why certain transformations intuitively strike us as better magic tricks, I conducted an experiment in which people answered a simple question – judging how interesting a trick would be – for a variety of transformations. Asking the question for the same transformation in different directions (across different participants) provides the opportunity to examine the robustness of the asymmetry. By also collecting judgments of similarity and the interestingness of tricks featuring the appearance and disappearance of different objects, the influence of the direction of movement in the hierarchy could be assessed while controlling for other possible explanations for the asymmetry.

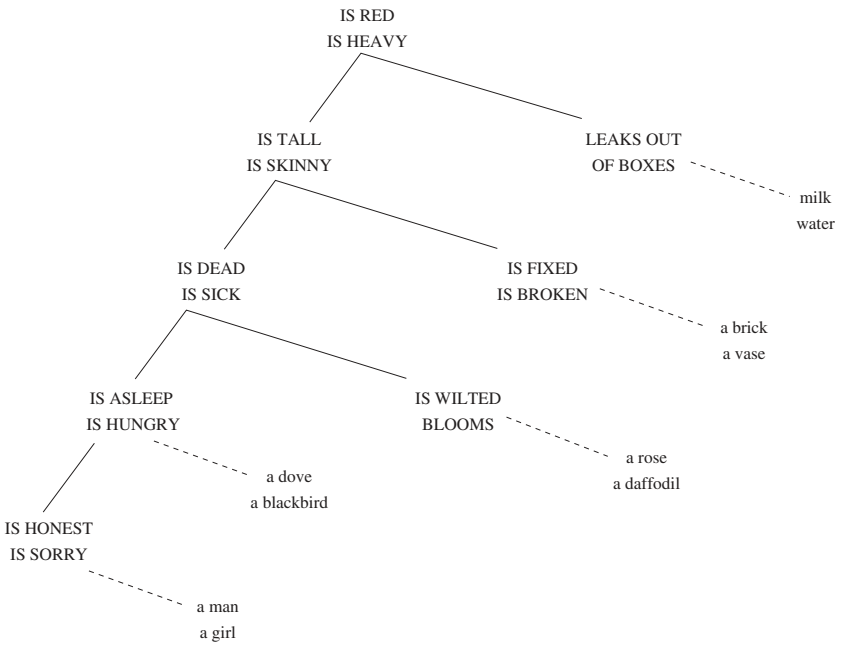

Fig. 1. Ontological commitments as reflected in a predicability hierarchy. Predicates appear in capitals, entities in lowercase. An entity can have any of the predicates that appear along the path from the root to the entity. Modified from Keil (1979).

1. Experiment 1: Asymmetries in magical transformations

1.1. Method

1.1.1. Participants

Participants were 40 university community members, recruited through advertisements on campus and participating in exchange for reimbursement of $10 per hour. Participants were randomly assigned to two conditions – the Magic and Similarity conditions – for a total of 20 participants in each condition.

1.1.2. Materials

The participants completed a survey asking for a series of judgments about different entities. The ten entities shown in Fig. 1 (milk, water, brick, vase, a rose, a daffodil, a dove, a blackbird, a man, a girl) were used. The main part of the survey consisted of a series of 90 judgments about pairs of objects. In the Magic condition, the instructions given for these judgments were:

> Pretend that you are working as a magician's assistant. The magician is working on his act, and is trying to figure out which tricks would be the most interesting to an audience. Please rate how interesting you think the following tricks would be on a scale from 1 to 10 (with 1 being the least interesting, and 10 being the most interesting).

The pairwise judgments were then presented in sequence, described as "Transform *X* into *Y*" for entities *X* and *Y* drawn from the list given above. All 45 possible pairs of entities from this list were included. In the Similarity condition, the instructions were:

> People have different intuitions about the relationship between things. How similar do you find each of the following pairs of objects on a scale from 1 to 10 (with 1 being the least similar and 10 being the most similar)?

The pairwise judgments then simply identified two entities *X* and *Y* for which the similarity should be evaluated.

The survey used in the Magic condition also had two more sets of ten items mixed into the list of tricks to be evaluated. These were "Make *X* appear" and "Make *X* disappear", for *X* ranging over all ten entities.

1.1.3. Procedure

Four randomized versions of each survey were constructed. Randomization changed the order in which pairs of entities appeared in the survey (and single entities for the "appear" and "disappear" questions). Participants completed the survey in the laboratory during a session in which they also took part in other unrelated experiments.

1.2. Results and discussion

One participant in the Magic condition produced responses that were negatively correlated with all other participants, suggesting a scale reversal, and was omitted from further analyses. All ratings were normalized by conversion into *z* scores for each participant. The mean ratings for all pairs of objects in all conditions appear in Fig. 2(a). The critical question was whether the judgments of the interestingness of magic tricks were affected by the direction that the transformation took in the assumed hierarchy (Fig. 1). As a simple initial analysis, the degree of asymmetry was examined by subtracting the mean responses for the transformation up the hierarchy from the mean responses for the transformation down the hierarchy. The results are shown in Fig. 2(b). There is a clear asymmetry in this pattern, with transformations down the hierarchy being more interesting (positive sign for 33 of the 40 relevant transformations, Binomial test $p < .0001$).[1] However, there are also other factors that clearly influenced responses, such as whether a trick involved people (which made tricks much more interesting in general).

To provide a more quantitative investigation, a regression analysis was performed. The predictors in the regression model were selected to control for various alternative explanations: the effect being driven by similarity, or resulting from other factors such as adding features when moving down the hierarchy that might also be expected to influence similarity judgments (Tversky, 1977); the appearance or disappearance of an object, both of which are part of a transformation, differing in salience; the strong influence of involving people in a magic trick. Accordingly, the predictors were the mean similarity between items, the mean interestingness of making the object that was the end point of the transformation appear, the mean interestingness of making the object that was the starting point of the transformation disappear, whether the transformation involved people (coded as 1 or 0), and the direction in the hierarchy (with down coded as 1, no difference as 0, and up as -1). The results are shown in Table 1, with the full model giving $R(84) = 0.952$. All four factors were statistically significant, indicating that magic tricks that transformed an object into one lower on the hierarchy were statistically significantly more interesting than transformations in the reverse direction.

The results indicate that people's ontological commitments have a strong effect on their judgment of the interestingness of magic tricks, resulting in systematic asymmetries in the evaluation of different kinds of magical transformation. However, it is natural to ask whether a similar effect can be obtained without making a direct appeal to magic. Developmental research has explored how children relate the effects of magic from those of physical mechanisms (Chandler & Lalonde, 1994; Johnson & Harris, 1994; Phelps & Woolley, 1994; Rosengren & Hickling, 1994). To explore people's intuitions about physical mechanisms, I ran a second experiment in which people were asked to evaluate the plausibility of mechanical transformations performed in different directions.

[1] Since asymmetries also appear in similarity judgments (Tversky, 1977), a similar test was conducted on the mean similarity judgments. Only 24 out of 40 pairs (Binomial test $p = .27$) were judged to be more similar down the hierarchy than up the hierarchy.

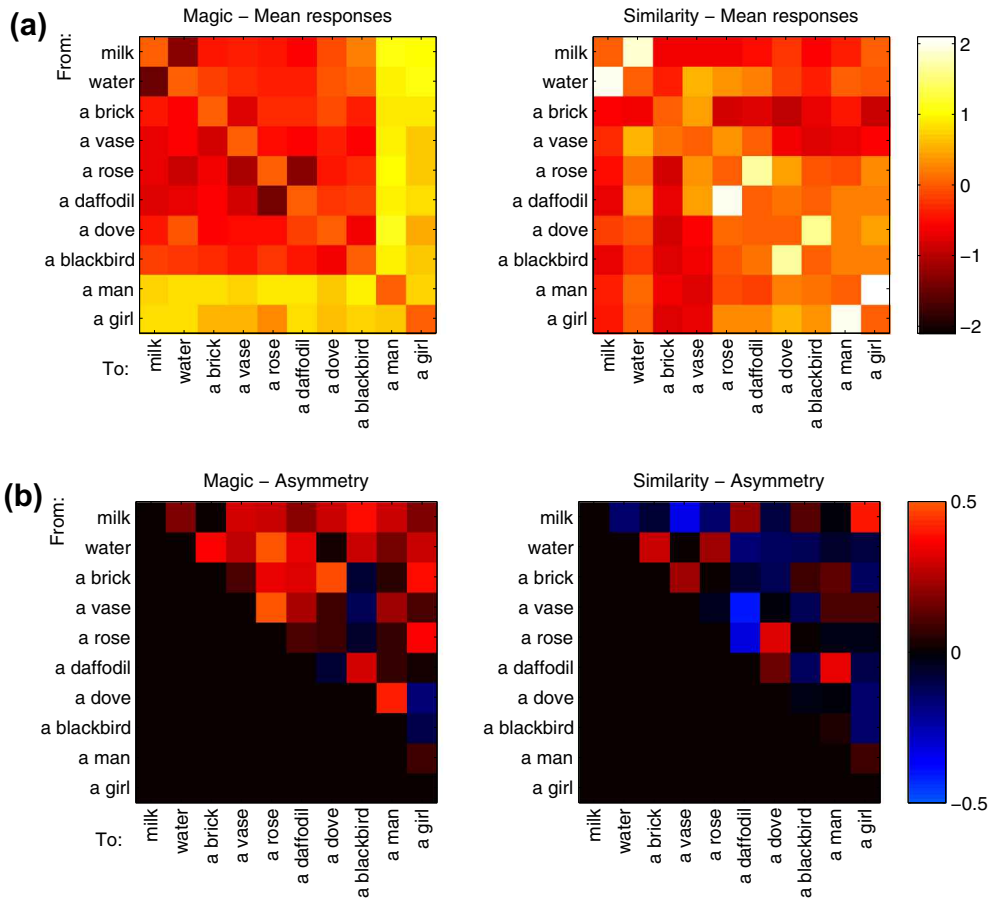

Fig. 2. Results of Experiment 1. (a) Judgments of interestingess of magic tricks and similarity, from the entity on the rows to the entity on the columns. (b) Asymmetry in judgments, as shown by subtracting the ratings below the diagonal of the matrix from the ratings above the diagonal.

Table 1
Regression analysis of mean interestingness judgments for magic tricks in Experiment 1.

Factor	Coefficient (standard error)	t	p
Similarity	−0.22 (0.031)	−7.19	<.0001
Appearing object	0.13 (0.036)	3.55	.0006
Disappearing object	0.17 (0.045)	3.83	.0003
People	0.74 (0.12)	6.36	<.0001
Direction in hierarchy	0.084 (0.031)	2.78	.0067

2. Experiment 2: The plausibility of mechanical transformations

2.1. Method

2.1.1. Participants

Participants were 20 university community members, recruited through advertisements on campus and participating in exchange for reimbursement of $10 per hour. These participants had not taken part in Experiment 1.

2.1.2. Materials

The transformations were presented in a survey that took the same form as that used in the Magic condition of Experiment 1. The instructions read:

> Imagine you were reading the newspaper, and came across an article describing a newly invented machine that was designed to produce one of the effects listed below. How likely would you think it was that the machine could actually produce this effect? For each effect, rate how likely you think it is that a newly invented machine could produce that effect, using a scale from 1 to 10 (with 1 indicating that it is very unlikely that machine could produce the effect, and 10 indicating that it is very likely that the machine could produce the effect).

The pairwise judgments were then presented in sequence, described as "Transform *X* into *Y*" for all 90 pairs of entities *X* and *Y* or "Make *X* appear" and "Make *X* disappear"for *X* ranging over all ten entities.

2.1.3. Procedure

Four randomized versions of the survey were constructed, using the same random orders of transformations, appearances, and disappearances as in the Magic condition in Experiment 1. Participants completed the survey in the laboratory during a session in which they also took part in other unrelated experiments.

2.2. Results and discussion

All ratings were normalized as in Experiment 1. The mean plausibility of mechanical transformations was moderately negatively correlated with the mean interestingness of magic tricks $r(88) = -0.478$. Ratings of the plausibility of different mechanical transformations showed initial evidence for an asymmetric effect of the direction of movement: for 32 out of 40 pairs, the transformation down the hierarchy was rated less plausible than the transformation up the hierarchy (Binomial test, $p < .0005$). However, the effect of direction was not statistically significant when a regression analysis similar to that used in Experiment 1 was conducted. The regression included the similarity ratings from Experiment 1, the plausibility of mechanically making objects appear and disappear, the involvement of people, and the direction in the hierarchy as predictors. The results are shown in Table 2, with the full model giving $R(84) = 0.816$. The only statistically significant predictors were similarity and the plausibility of making an object appear, in contrast to the results for magic tricks observed in Experiment 1.

The results of this experiment suggest that ontological commitments have a weaker effect on judgments about the physical mechanisms than they do on judgments about magic tricks. While raw judgments showed some evidence of an asymmetry, direction in the hierarchy did not have a significant effect once other possible factors were controlled for. However, there were two differences between the task in Experiments 1 and 2: whether the transformation was magical or mechanical, and whether the question was interestingess or plausibility. To tease apart the effects of these two factors, I conducted another experiment.

3. Experiment 3: The interestingess of mechanical transformations

3.1. Method

3.1.1. Participants

Participants were 20 university community members, recruited through advertisements on campus and participating in exchange for reimbursement of $10 per hour. These participants had not taken part in Experiments 1 or 2.

3.1.2. Materials

The transformations were presented in a survey that took the same form as that used in the Magic condition of Experiment 1. The instructions read:

> Imagine you were reading the newspaper, and you came across an article describing a newly invented machine that was designed to produce one of the effects listed below. How interesting do you think other people would find this machine? Please rate how interesting you think the following effects are, using a scale from 1 to 10 (with 1 being the least interesting and 10 being the most interesting).

The pairwise judgments were then presented in sequence, described as "Transform *X* into *Y*" for all 90 pairs of entities *X* and *Y* or "Make *X* appear" and "Make *X* disappear" for *X* ranging over all ten entities.

3.1.3. Procedure

Four randomized versions of the survey were constructed, using the same random orders of transformations, appearances, and disappearances as in the Magic condition in Experiment 1. Participants completed the survey in the laboratory during a session in which they also took part in other unrelated experiments.

3.2. Results and discussion

One participant produced responses that were negatively correlated with those of all other participants, suggesting a scale reversal, and was omitted from all other analyses. All ratings were normalized as in Experiments 1 and 2. The mean ratings for interestingness of mechanical transformations were strongly correlated with the interestingness of magic tricks ($r = 0.912$) and moderately negatively correlated with the plausibility of mechanical transformations ($r = -0.599$). The mechanical interestingness ratings showed evidence of an asymmetric effect of the direction of movement: for 34 out of 40 pairs, the transformation down the hierarchy was rated more interesting than the transformation up the hierarchy (Binomial test, $p < .0001$). A regression analysis similar to that performed in Experiments 1 and 2 showed a statistically significant effect of similarity, whether the transformation involved people, and direction in hierarchy (albeit slightly weaker than that observed in Experiment 1). The results are shown in Table 3, with the full model giving $R(84) = 0.909$. Interestingness, rather than whether the transformation is the result of magical or mechanical forces, thus seems to be the critical factor linking people's

Table 2
Regression analysis of mean plausibility judgments for machines in Experiment 2.

Factor	Coefficient (standard error)	*t*	*p*
Similarity	0.19 (0.019)	10.34	<.0001
Appearing object	0.19 (0.047)	4.04	.0001
Disappearing object	0.049 (0.058)	0.85	.40
People	−0.094 (0.079)	−1.21	.23
Direction in hierarchy	−0.008 (0.052)	−0.15	.88

Table 3
Regression analysis of mean interestingness judgments for machines in Experiment 3.

Factor	Coefficient (standard error)	*t*	*p*
Similarity	−0.91 (0.020)	−4.73	<.0001
Appearing object	−0.039 (0.029)	−1.32	.18
Disappearing object	−0.028 (0.037)	−0.80	.44
People	1.16 (0.10)	12.20	<.0001
Direction in hierarchy	0.12 (0.048)	2.48	.013

intuitions about transformations to their ontological commitments.

4. General discussion

Adults' intuitions about the interestingness of magic tricks reveal their ontological commitments. Experiment 1 showed that there is an asymmetry in which transformations that go "down" the ontological hierarchy – increasing the set of applicable predicates – are more interesting than tricks that go "up" the ontological hierarchy. This effect is not simply due to asymmetries in similarity, differences in the interestingess of the disappearance and appearance of the entities involved in the transformation, or the involvement of people in tricks. Experiment 2 showed that this effect is not observed (or at least not as strong) for judgments about the plausibility of physical mechanisms being able to perform these transformations. But Experiment 3 showed that ontological commitments do affect judgments of the interestingness of machines that can perform these transformations.

The small effect of whether the transformation is magical or mechanical is perhaps not surprising – current technology cannot perform many of these transformations, and as Clarke (1973) wrote "Any sufficiently advanced technology is indistinguishable from magic." If people are treating machines capable of such transformations as a mysterious "black box," then their judgments are likely to tap the same intuitions as magic tricks, although perhaps less directly. But why should there be a difference between plausibility and interestingness? A possible answer is provided by the theory of coincidences proposed by Griffiths and Tenenbaum (2007), in which a coincidence is defined as an event that provides strong evidence for an a priori unlikely alternative to a current theory. Coincidences – which inspire our sense of interest in much the same way as magic – thus need to be both unlikely under our current theory, and more likely under the alternative. The plausibility of transformations measures only the probability under a mechanical theory, while a good magic trick is good precisely because it suggests the operation of forces that go beyond those we believe exist. Likewise, a machine that can perform a novel transformation suggests an opportunity to revise our physical theory.

Magic tricks provide a particularly pure guide to people's ontological commitments, suggesting several directions for future research. One direction is to confirm that the effects found in these survey-based experiments transfer to real magic tricks – certainly relevant before conjurors use these results when designing their acts. But the more theoretically interesting direction is to examine what other ontological commitments are reflected in our beliefs about magic, and whether it is possible to reconstruct aspects of human conceptual ontologies – such as the kind of hierarchy studied here – simply by soliciting intuitions about magic tricks.

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