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Brief article

Disentangling multimodal processes in social categorization

Michael L. Slepian

Columbia University, United States

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ABSTRACT

The current work examines the role of sensorimotor processes (manipulating whether visual exposure to hard and soft stimuli encourage sensorimotor simulation) and metaphor processes (assessing whether participants have understanding of a pertinent metaphor: "hard" Republicans and "soft" Democrats) in social categorization. Using new methodology to disassociate these multimodal processes (i.e., semantic, metaphoric, and sensorimotoric), the current work demonstrates that both sensorimotor and metaphor processes, combined, are needed to find an effect upon conceptual processing, providing evidence in support of the combined importance of these two theorized components. When participants comprehended the metaphor of hard Republicans and soft Democrats, and when encouraged to simulate sensorimotor experiences of hard and soft stimuli, those stimuli influenced categorization of faces as Republican and Democrat.

1. Introduction

With growing interest in the role sensorimotor states and metaphor play in cognition, researchers have highlighted the importance of examining the mechanisms of grounded effects upon judgments (Lee & Schwarz, 2012; Meier, Schnall, Schwarz, & Bargh, 2012). Prior work, for example, demonstrates that sensorimotor experiences of smiling influence humor judgments (Strack, Martin, & Stepper, 1988), cleanliness sensations influence moral judgments (Schnall, Benton, & Harvey, 2008; Zhong & Liljenquist, 2006), sweet tastes influence prosociality (Meier, Moeller, Riemer-Peltz, & Robinson, 2012), and hard/soft sensations influence face categorization (Slepian, Rule, & Ambady, 2012; Slepian, Weisbuch, Rule, & Ambady, 2011). For instance, experiencing hard and soft sensations leads individuals to categorize faces more often as Republicans and Democrats, respectively (Slepian et al., 2012).

In attempting to understand the mechanisms of such effects, researchers have primarily focused on inferring concepts' representational structures from the directionality of influences between sensorimotor and conceptual processing. The two prominent models of grounded cognition make different predictions for the directionality of such effects. Conceptual Metaphor Theory (CMT; Lakoff & Johnson, 1980) suggests metaphors serve the epistemic function of making abstract concepts more concrete; thus concrete sensations are metaphorically mapped onto abstract concepts (but abstract concepts are not mapped onto concrete sensations that are already concretely experienced). CMT therefore proposes that sensorimotor processes can influence conceptual processes in line with a metaphor, but the reverse direction of influence does not occur. Perceptual Symbol Systems (PSS) theory, however, suggests metaphors arise from experiential correlations between sensorimotor and conceptual activations (Barsalou, 1999, 2008). PSS predicts that the representational structure of abstract concepts is perceptual in nature, consisting of multimodal states associated with experience with the abstract concept; metaphor develops out of these multimodal associations (i.e., such multimodal

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activity serves as a *perceptual symbol* for the concept). PSS, then, predicts that sensorimotor processing should influence conceptual processing, and reciprocally, conceptual processing should influence sensorimotor processing via simulations (i.e., partial reactivations of multimodal states previously experienced with the abstract concept). For example, physical warmth leads individuals to act more interpersonally warm (Williams & Bargh, 2008), and interpersonal warmth influences the sensory processing of physical warmth (Zhong & Leonardelli, 2008).

When researchers have found bidirectional influences between sensorimotor and conceptual processing they have suggested that this provides evidence that sensorimotor activity is a perceptual symbol for an abstract concept, rather than a metaphor. This is problematic because this conclusion falls out of an untested assumption of the prominent model of conceptual metaphor. CMT hypothesizes that learning a metaphor will lead to unidirectional influences between sensorimotor processing and conceptual processing, but not the reverse. This assumption was only recently tested, and Slepian and Ambady (2014) demonstrated that learning a metaphor can lead to the reverse direction of influence: conceptual processing influencing sensorimotor processing. This finding is inconsistent with the CMT account by demonstrating an influence of metaphor upon sensorimotor processing, and a strict perceptual experience-based PSS account as well by demonstrating that a metaphor learned outside of sensorimotor experience can have sensorimotor consequences.

These recent findings thus challenge the two prominent models of grounded cognition, but the Simulated Sensorimotor Metaphor (SSM) model (Slepian & Ambady, 2014) – proposed to explain how learned metaphors can lead to such bidirectionality – has itself not been tested. This was the goal of the current work. Contrary to CMT and PSS, the SSM model proposes that such grounded influences upon conceptual processing are both metaphor-based and sensorimotor-based.

SSM suggests that due to bidirectional links between sensorimotor and higher-order binding areas made when forming a representation of a concept (Damasio, 1989; McClelland, McNaughton, & O'Reilly, 1995), learning a metaphor can lead to incorporation of sensations (multimodal states) into the concept's representational structure. Merely conceiving of sensorimotor experience leads to modality-specific simulations of those experiences (Belardinelli et al., 2009). SSM thus proposes that a learned metaphor, which references sensorimotor experience, leads consequent sensorimotor activations (from simulations) to become linked to co-occurring conceptual processing. SSM thus suggests that grounded effects upon conceptual processing should be seen to the extent that both metaphor and sensorimotor processes are engaged. To disassociate these multimodal processes in grounded judgments (i.e., semantic, metaphoric, and sensorimotoric), the current work uses a novel method of estimating the role of sensorimotor and metaphor processes by examining their combined importance, relative to semantic processes, in influencing metaphor-consistent judgments.

Building upon the finding that hard and soft sensorimotor experiences influence categorization of faces (e.g., as Republican and Democrat), the current work introduces two methodological approaches to addressing these questions of mechanism, (1) designing highly matched stimuli that convey the semantic content of sensorimotor experiences, or those that also encourage the simulation of the sensorimotor experiences that those stimuli provide, and (2) measuring metaphor comprehension (and estimating the level of metaphor comprehension necessary to find effects). These methods assist in examining the mechanisms of grounded effects upon conceptual processing. For the present example, is mere semantic activation of hard and soft concepts sufficient to influence categorization of faces in metaphorically congruent ways (i.e., categorizing Republicans with "hard," and Democrats with "soft," activations)? Alternatively, is sensorimotor processing of hardness and softness needed for hard and soft stimuli to influence categorization in ways consistent with a metaphor referencing those sensorimotor experiences?

Moreover, to what extent are these effects based in individual metaphor awareness and understanding? For instance, if an individual does not understand, or is less familiar with, the metaphor of Republicans as "hard" politicians, and Democrats as "soft" politicians, would these effects be less likely to occur? Answering these questions would assist in understanding the mechanisms underlying grounded cognition effects by determining whether these effects are consequences of semantic priming, or are sensorimotor based. Indeed, current critiques of grounded cognition hypotheses center on the lack of evidence for the role of sensorimotor processes in judgment and conception (Mahon & Caramazza, 2008). The current work thus tests the SSM model's hypothesis that such grounded effects upon conceptual processing are both metaphor-based and sensorimotor-based.

2. Method

An a priori power analysis determined 196 participants were needed to demonstrate a small-to-medium effect ($f^2 = .04$, $\alpha = .05$, power = .80). Accordingly, in two experiments, 196 MechanicalTurk participants (Experiment 1: $M_{age} = 34.57$ years, $SD = 12.06$; 105 male, 91 female; Experiment 2: $M_{age} = 32.38$ years, $SD = 10.29$, 81 male, 115 female) were asked to categorize eight gray-scale faces (half male, half female) as appearing to be a Republican or a Democrat (as in Slepian et al., 2012). Half of the faces were presented next to a hard object (e.g., a wooden block, a rock), and the remaining faces were presented next to a soft object (e.g., cotton balls, a pillow). Participants were provided with a cover story about processing multiple images, and asked to categorize faces, but also to pay attention to the objects for an ostensible later part of the study. The face-object pairings were counterbalanced across participants, and randomly presented. Lastly, participants completed a metaphor-comprehension measure. Participants were asked to judge how much sense it made that *other people* might call a Republican a "hard politician"

and a Democrat a "soft politician" (a mean was taken; Table 1). Because one goal of the current work was to estimate the level of metaphor comprehension necessary to find metaphor-consistent categorization effects, the metaphor comprehension prompt specifically avoided asking participants directly if *they* understood the metaphor as such prompts often lead to over-claiming comprehension, making point estimates difficult (see Paulhus, Harms, Bruce, & Lysy, 2003). Instead, it was reasoned that asking participants how much sense it made that other people might use such language would actually more faithfully reflect their own comprehension of the metaphor.

To manipulate sensorimotor simulation in Experiment 1, participants were randomly assigned to see an image of an object semantically linked to hardness or softness (*objects only*) presented to the right of a face, or view the same objects in a manner that might encourage participants to simulate the sensorimotor experience of hardness or softness that those objects provide (*simulation encouraged*). Prior work suggests that exposure to a hand interacting with an object might lead to simulations of the sensorimotor experience the object provides. For example, exposure to a hand interacting with an object can lead to simulations of the experienced heaviness of the object (Asai, Sugimori, & Tanno, 2012), or pain from the object (e.g., from interacting with a sharp object; Benuzzi, Lui, Duzzi, Nichelli, & Porro, 2008; see also Avikainen, Forss, & Hari, 2002; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Rossi et al., 2002; Schaefer, Xu, Flor, & Cohen, 2009; Voisin et al., 2011). Thus, in the current study, seeing a hand interacting with a hard (soft) object might encourage simulation of the objects' hardness (softness).

Possibly, the presence of hands holding objects might not encourage sensorimotor simulation per se, but rather simply call greater attention to the hardness/softness of the objects. To examine this possibility, Experiment 2 replicated Experiment 1's procedure, but rather than present objects alone, objects were held by gloved hands. This latter condition calls attention to the objects, similar to ungloved hands, but the pictured (thick) gloves render

Table 1
Scale points for metaphor comprehension prompt.

Scale point	Label
1	Makes no sense
2	Makes a little sense
3	Makes some sense
4	Makes sense
5	Makes a good amount of sense
6	Makes a lot of sense
7	Makes perfect sense

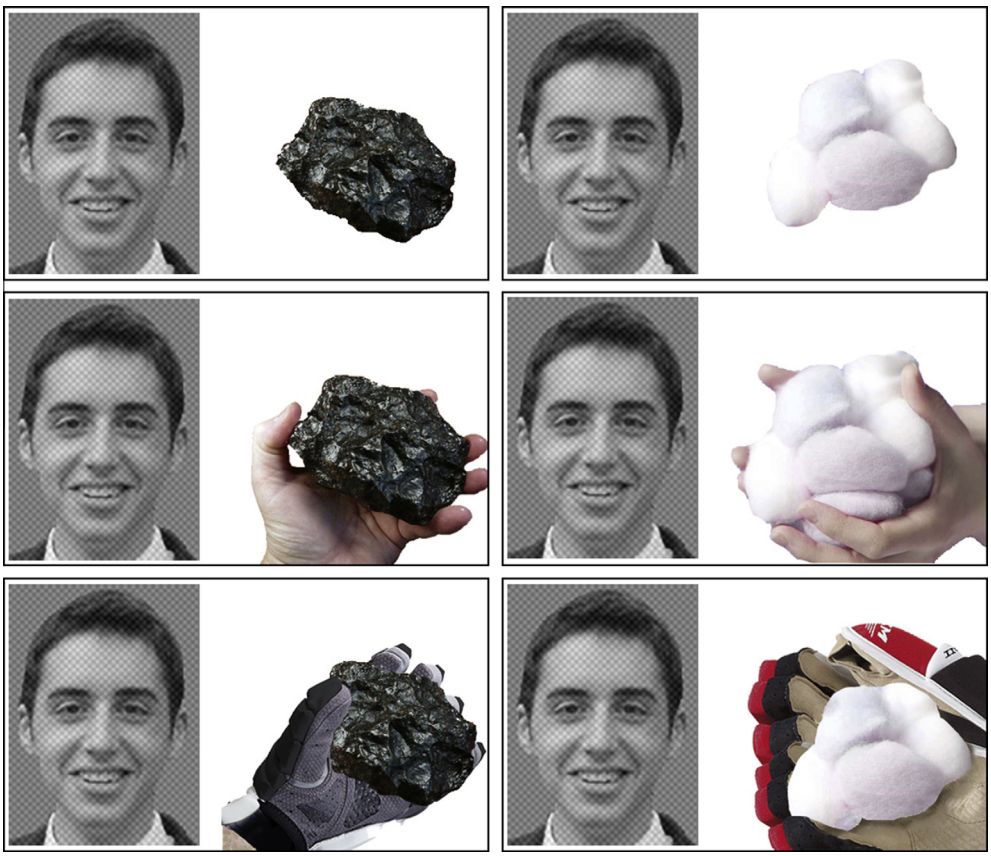

Fig. 1. Example stimuli (Experiment 1: rows 1–2, Experiment 2: rows 2–3).

the hand inside relatively insensitive to the hardness/softness of the objects (Fig. 1).

First, to the extent that these effects rely on individual metaphorical cognition, they should diminish with decreased metaphor comprehension, and be enhanced with increasing comprehension. Second, if the nature of this metaphor is only a semantic link, increasing comprehension of the metaphor should increase metaphor-consistent categorization for all conditions. Alternatively, if as SSM predicts, the link is metaphor-based and sensorimotor-based, then increasing comprehension of the metaphor should increase metaphor-consistent categorization only when participants are encouraged to simulate sensorimotor experiences (via ungloved hands holding the objects).

3. Results

During debriefing, one Experiment 1 participant mentioned suspecting a relationship between objects and faces and was thus excluded from analysis (including this participant does not alter any patterns of relationships or significance). For both experiments, a count was taken of the number of faces categorized as Republican (vs. Democrat) with hard stimuli, and separately with soft stimuli, and the latter was subtracted from the former. This index of *metaphor-consistent categorization* thus increases with hard stimuli leading to Republican categorizations and soft stimuli leading to Democrat categorizations (negative numbers on this index indicate the reverse association, and zero indicates no association). Calculating the metaphor-consistent categorization dependent variable allows for predicting (from both simulation encouragement and metaphor independent variables) an index that captures the strength of the influence of hard stimuli on Republican categorizations and soft stimuli on Democrat categorizations.

3.1. Experiment 1

A hierarchical regression was conducted, which included stimuli-condition (*object-only*, *objects-with-hands*) and centered metaphor-comprehension scores (Step 1), and the interaction term (Step 2), as predictors of metaphor-consistent categorization. There was no main effect of stimuli-condition, $b = .14$, $t(192) = 1.31$, $p = .19$, but metaphor-comprehension positively predicted metaphor-consistent categorization, $b = .19$, $t(192) = 2.73$, $p = .007$; greater comprehension of the hard-Republican/soft-Democrat metaphor was associated with greater metaphor-consistent categorization; Step-1 $R^2 = .05$, $F(2,192) = 4.59$, $p = .01$.

These effects were qualified, however, by a stimuli-condition × metaphor-comprehension interaction, $b = .14$, $t(191) = 2.03$, $p = .04$; Step-2 $R^2 = .07$, $F(3,191) = 4.48$, $p = .005$; $\Delta R^2 = .02$. Simple slope analyses revealed that when presenting objects only, there was no relationship between metaphor-comprehension and metaphor-consistent categorization, $b = .05$, $t(191) = 0.48$, $p = .63$. In contrast, when those same objects were shown with hands interacting with them, metaphor-comprehension was a significant predictor of metaphor-consistent categorization, $b = .33$, $t(191) = 3.38$, $p = .001$ (Fig. 2). Increasing metaphor comprehension was associated with an increased likelihood of metaphor-consistent categorization when participants were encouraged to simulate hard and soft sensorimotor experiences of objects (q.v. Experiment 2), but this relationship did not exist when participants viewed objects without hands (i.e., no simulation encouragement).

To further probe this interaction, Hayes and Matthes's (2009) modprobe-macro was used to implement the Johnson-Neyman technique, which provides an alternative to traditional estimations of moderation that require selecting arbitrary values of the moderator at which to assess significance of the predictor (e.g., ±1 *SD* from the mean; Aiken & West, 1991) by revealing the predictor's significance at all ranges of the moderator. This provides a more complete picture of moderation patterns than do traditional methods.

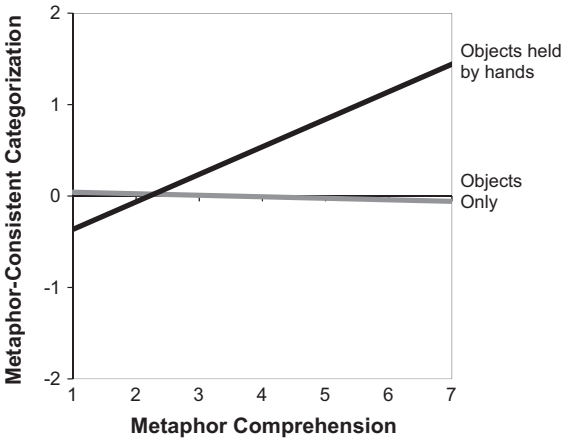

Fig. 2. Metaphor-consistent categorization as a function of metaphor comprehension and encouraging sensorimotor simulation (objects held by hands) vs. not (objects only) in Experiment 1.

Table 2
Johnson-Neyman technique applied to Experiment 1: Regions of significance for the conditional effect of encouraging sensorimotor simulation of hardness and softness (vs. not) on metaphor-consistent categorization as a function of metaphor comprehension. Values in boldface indicate the conditional effect was a significant predictor.

Metaphor comprehension	*b*	95% CI on *b*		*t*	*p*
		LL	UL		
1.00	−0.130	−0.464	0.204	−0.77	.44
1.50	−0.060	−0.343	0.224	−0.41	.68
2.00	0.011	−0.231	0.253	0.09	.93
2.50	0.081	−0.134	0.296	0.75	.46
3.00	0.152	−0.056	0.360	1.44	.15
3.50	0.222	−0.001	0.445	1.96	.05
3.51	**0.224**	**0.000**	**0.447**	**1.97**	**.05**
4.00	**0.293**	**0.037**	**0.549**	**2.25**	**.03**
4.50	**0.363**	**0.062**	**0.664**	**2.38**	**.02**
5.00	**0.433**	**0.079**	**0.787**	**2.41**	**.02**
5.50	**0.504**	**0.092**	**0.915**	**2.41**	**.02**
6.00	**0.574**	**0.102**	**1.046**	**2.40**	**.02**
6.50	**0.645**	**0.110**	**1.179**	**2.38**	**.02**
7.00	**0.715**	**0.117**	**1.313**	**2.36**	**.02**

This analysis revealed that the effect of encouraging simulation on metaphor-consistent categorization got stronger as metaphor comprehension increased (Table 2), and encouraging simulation, relative to not, became a significant predictor of metaphor-consistent categorization when participants' comprehension of the metaphor reached 3.51 or higher, that is, just as they indicated having comprehension of the metaphor (see Tables 1 and 2). The manipulation did not affect metaphor-consistent categorization, however, when participants reported that it made little sense that others might use such language, indicating non-comprehension of the metaphor. Thus, only for participants that indicate having comprehension of the metaphor does encouraging sensorimotor simulation of hardness and softness lead to metaphor-consistent categorization.

3.2. Experiment 2

One possibility is that the objects-with-hands condition in Experiment 1 did not encourage simulation, but simply called greater attention to the objects. Applying the same analysis plan to Experiment 2 demonstrates that these results were not contingent on the presence of hands calling greater attention to objects given that gloved hands (relatively insensitive to hardness/softness) operated similarly to objects presented without hands. There was no main effect of stimuli-condition, $b = -.07$, $t(193) = -0.29$, $p = .77$, but a main effect of metaphor-comprehension, whereby metaphor-comprehension positively predicted metaphor-consistent categorization, $b = .29$, $t(193) = 3.99$, $p < .0001$; Step-1 $R^2 = .08$, $F(2,193) = 7.97$, $p < .001$. These effects were qualified, however, by a stimuli-condition × metaphor-comprehension interaction, $b = .29$, $t(192) = 1.98$, $p = .05$; Step-2 $R^2 = .10$, $F(3,192) = 6.68$, $p < .001$; $\Delta R^2 = .02$. Simple slope analyses revealed that metaphor-comprehension positively predicted metaphor-consistent categorization when objects were held by ungloved hands, $b = .41$, $t(192) = 4.33$, $p < .0001$, but not gloved hands, $b = .13$, $t(192) = 1.15$, $p = .25$ (Fig. 3).

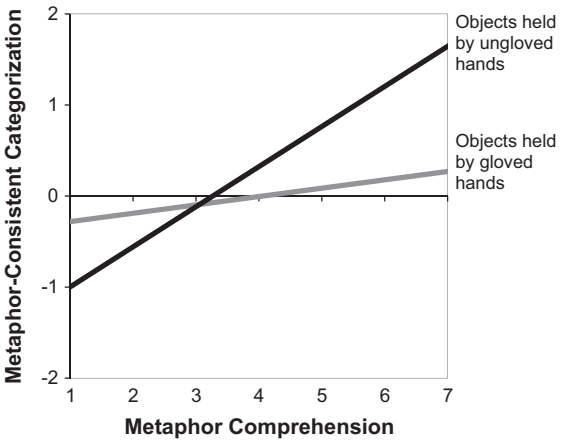

Fig. 3. Metaphor-consistent categorization as a function of metaphor comprehension and encouraging sensorimotor simulation (objects held by ungloved hands) vs. not (objects held by gloved hands) in Experiment 2.

Table 3
Johnson-Neyman technique applied to Experiments 1 and 2, combined: Regions of significance for the conditional effect of encouraging sensorimotor simulation of hardness and softness (vs. not) on metaphor-consistent categorization as a function of metaphor comprehension. Experiment is included as a covariate, but excluding this covariate does not change the pattern of results or significance. Values in boldface indicate the conditional effect was a significant predictor.

Metaphor comprehension	*b*	95% CI on *b*		*t*	*p*
		LL	UL		
1.00	−0.453	−0.948	0.043	−1.80	.07
1.50	−0.311	−0.733	0.112	−1.44	.15
2.00	−0.169	−0.530	0.193	−0.92	.36
2.50	−0.027	−0.347	0.293	−0.16	.87
3.00	0.115	−0.190	0.421	0.74	.46
3.50	0.257	−0.065	0.580	1.57	.12
3.82	**0.348**	**0.000**	**0.696**	**1.97**	**.05**
4.00	**0.399**	**0.033**	**0.766**	**2.14**	**.03**
4.50	**0.542**	**0.113**	**0.970**	**2.48**	**.01**
5.00	**0.684**	**0.181**	**1.187**	**2.67**	**.008**
5.50	**0.826**	**0.241**	**1.410**	**2.79**	**.006**
6.00	**0.968**	**0.297**	**1.638**	**2.84**	**.005**
6.50	**1.110**	**0.350**	**1.869**	**2.87**	**.004**
7.00	**1.252**	**0.401**	**2.103**	**2.89**	**.004**

These results suggest that the presence of hands does not strengthen the relationship between metaphor-comprehension and metaphor-consistent categorization by simply calling greater attention to hard/soft stimuli. Rather, what seems crucial is that the presented hands are capable of experiencing the sensory qualities of the stimuli. It should be noted, however, that while simple slope analyses make clear that metaphor-comprehension predicted metaphor-consistent categorization when objects where held by ungloved hands only, the interaction *p*-value only *equaled* .05. Therefore, the simple slopes did not differ at *p less* than .05; but, as in Experiment 1, as shown by the Johnson-Neyman technique, encouraging simulation predicts metaphor-consistent categorization more strongly with increasing metaphor-comprehension (and crosses the $\alpha = .10$ threshold at 6.37).

3.3. Overall metaphor comprehension point estimate

A more profitable Johnson-Neyman analysis applies the technique to the combined data from both experiments (rather than each separately) to capture a more reliable point estimate. Doing so (with including Experiment as a covariate, which does not change the pattern of results or significance) reveals that, combining experiments, encouraging simulation (vs. not), becomes a significant predictor of metaphor-consistent categorization at 3.82 or higher, that is, just as participants indicated having comprehension of the metaphor (Tables 1 and 3; stimuli-condition × metaphor-comprehension interaction, $b = .28$, $t(386) = 2.83$, $p = .005$; without Experiment covariate, stimuli-condition × metaphor-comprehension interaction, $b = .28$, $t(387) = 2.79$, $p = .006$).

4. Discussion

Two experiments demonstrated that the influence of hard and soft stimuli upon social categorization is dependent on the *combined* effect of sensorimotor and

metaphor processes. The greater participants' comprehension of the hard-Republican/soft-Democrat metaphor, the more they demonstrated metaphor-consistent categorization. This was only the case, however, when participants were encouraged to simulate the sensorimotor experience of the hard and soft stimuli via presenting hands interacting with objects, and capable of experiencing their sensory qualities.

If the present effects occurred via semantic priming, effects should be similar across all stimuli conditions, yet when objects were presented without hands, or with hands relatively insensitive to hard/soft stimuli (via wearing thick gloves), there was no relationship between metaphor comprehension and metaphor-consistent categorization, suggesting an important role for encouraging sensorimotor processing of the hard/soft stimuli.

These results are the first to isolate the importance of sensorimotor processes from semantic processes – in conjunction with the importance of metaphor comprehension – in a grounded effect upon conceptual processing. The current work also presents the first experimental evidence to confirm the predictions of the SSM model that grounded influences upon conceptual processing are both sensorimotor-based and metaphor-based, whereas prior work has described effects upon conceptual processing as either metaphor-based (CMT), or sensorimotor-based (PSS). Having comprehension of a metaphor that describes Republicans as "hard" politicians and Democrats as "soft" politicians has consequences for social-categorical judgments. Additionally, these metaphors seem sensorimotor-based, rather than solely semantic-based, given that exposure to hard and soft objects (in the absence of encouraging simulation) did not influence judgments, even among participants with understanding of the metaphor. These findings demonstrate the combined importance of both sensorimotor processes and metaphor comprehension in grounded cognition. As a further contribution, the current work estimated the level of metaphor comprehension needed in the current samples to find an influence of sensorimotor processes on judgment outcomes.

The current findings add to recent work demonstrating boundary conditions for grounded effects upon conceptual processing. For instance, Häfner (2013) demonstrated that sensations of weight led to greater value judgments, but only when participants demonstrated high interoceptive abilities. The current work nicely dovetails with Häfner's (2013) individual-difference approach by manipulating the engagement of sensorimotor processes. When exposed to hard and soft stimuli, if sensorimotor processes were not sufficiently engaged, these stimuli did not influence social categorization.

Importantly, the current work also demonstrated cognizance of the relevant metaphor as necessary: If one did not have comprehension of the hard-Republican/soft-Democrat metaphor, encouraging sensorimotor simulation of hardness and softness did not influence social categorization. Whereas prior work has suggested either metaphor or sensorimotor processes are inherent to sensorimotor influences upon conceptual processing, the current work presents evidence that the processes combined are important to demonstrating a grounded effect upon conceptual processing.

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