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Brief article

# Simulating sensorimotor metaphors: Novel metaphors influence sensory judgments

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ABSTRACT

Embodied cognition theory proposes that individuals' abstract concepts can be associated with sensorimotor processes. The authors examined the effects of teaching participants novel embodied metaphors, not based in prior physical experience, and found evidence suggesting that they lead to embodied simulation, suggesting refinements to current models of embodied cognition. Creating novel embodiments of abstract concepts in the laboratory may be a useful method for examining mechanisms of embodied cognition.


## 1. Introduction

Recent research suggests that a variety of abstract concepts are embodied within the sensorimotor system. For instance, concepts including importance, morality, time, and interpersonal traits and stereotypes have been linked to bodily sensations (Fay & Maner, 2012; IJzerman & Semin, 2009; Jostmann, Lakens, & Schubert, 2009; Lee & Schwarz, 2010; Meier, Moeller, Riemer-Peltz, & Robinson, 2012; Miles, Nind, & Macrae, 2010; Schnall, Benton, & Harvey, 2008; Schubert, 2005; Slepian, Rule, & Ambady, 2012; Williams & Bargh, 2008; Zhong & Liljenquist, 2006). With the recent proliferation of research examining embodied cognition, researchers have noted the importance of investigating the mechanisms underlying embodied concepts (such as the use of metaphor; Gibbs, 2006; Landau, Meier, & Keefer, 2010; Lee & Schwarz, 2012; Meier, Schnall, Schwarz, & Bargh, 2012; Williams, Huang, & Bargh, 2009). Two origins for embodied metaphors have been posited, but extant work has not directly manipulated these origins to examine their posited mechanisms. The current research teaches individuals novel embodied metaphors in the laboratory, therefore manipulating their origin, and examines whether such metaphors influence sensorimotor processing.

### 1.1. Models of embodied cognition

#### 1.1.1. Conceptual Metaphor Theory (CMT)

CMT (Lakoff & Johnson, 1980) describes embodied effects where sensation influences conceptual processing, but conceptual processing does *not* influence sensation. This asymmetry is described as inherent to the origin of embodied metaphors. To comprehend abstract concepts, concrete sensations are metaphorically mapped onto those concepts, serving an epistemic function, making abstract concepts more concrete (Lakoff & Johnson, 1999). CMT suggests the converse is not true: there is no need to consult an abstract concept to better comprehend directly-experienced concrete sensation and so mappings or influences in this direction are not predicted. CMT's hypotheses are therefore:

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*H.CMT.1:* Embodied metaphor (derived from learning) leads sensorimotor processing to influence conceptual processing.

*H.CMT.2:* Embodied metaphor (derived from learning) does *not* lead conceptual processing to influence sensorimotor processing.

#### 1.1.2. Perceptual Symbol Systems (PSS)

PSS (Barsalou, 1999) describes embodied effects that demonstrate bidirectionality. PSS suggests that abstract concepts consist of multimodal states associated with prior perceptuo-motor experience with such concepts, and that such experiential correlations result in embodied metaphors (i.e., metaphors are outcomes of perceptual-based knowledge representations, not inputs; cf. Barsalou, 2008). Conceiving of an abstract concept, then, leads to simulations, partial reenactments or reactivations of relevant multimodal states from prior experience. PSS's hypotheses are therefore:

*H.PSS.1:* Embodied metaphor (derived from prior experience) leads sensorimotor processing to influence conceptual processing.

*H.PSS.2:* Embodied metaphor (derived from prior experience) leads conceptual processing to influence sensorimotor processing.

#### 1.1.3. Simulated Sensorimotor Metaphor (SSM)

To add to these two prominent accounts, we propose a third account, the *Simulated Sensorimotor Metaphor* model, which bears resemblance to a combination of the two aforementioned models. First, notice that *H.CMT.1* and *H.PSS.1* make identical predictions for outcomes of embodied metaphors (though predict distinct origins). Thus, any influence of sensation upon conceptual processing cannot discriminate between the two; we therefore do not further discuss this direction of influence.

*H.CMT.2* and *H.PSS.2*, however, make opposing predictions. When conceptual processing influences sensation, such embodied effects are said to be best described by PSS. Physical warmth, for example, leads participants to judge others as interpersonally warm as well as behave in interpersonally warm ways (IJzerman, Karremans, Thomsen, & Schubert, 2013; Williams & Bargh, 2008; see also Macrae, Sunder Raj, Best, Christian, & Miles, 2013), and interpersonal warmth influences sensory processing of physical warmth (IJzerman et al., 2012; IJzerman & Semin, 2010; Szymków-Sudziarska, Chandler, IJzerman, Parzuchowski, & Wojciszke, 2013; Zhong & Leonardelli, 2008). Given this bidirectionality, which fits only both *H.PSS.1* and *H.PSS.2*, can it be concluded, as others have done previously, that physical warmth is a perceptual symbol for interpersonal warmth, rather than a metaphor? We argue, given that this conclusion falls only out of a specific model of metaphor (CMT, which predicts no bidirectionality), this does not necessarily follow. That is, perhaps another model of metaphor could account for these effects, and we propose the SSM model to suggest this possibility.

In reviewing the literature, we found a number of effects that seem to invoke metaphor, but demonstrate effects upon sensorimotor processing. For instance, suspicion enhances the ability to detect fishy smells, in alignment with a *suspicion-is-smelling-fishy* metaphor (Lee & Schwarz, 2012). Recalling personal secrets leads to judgments that indicate being physically burdened, in alignment with a *secrets-are-physical-burdens* metaphor (Slepian, Masicampo, & Ambady, 2013; Slepian, Masicampo, Toosi, & Ambady, 2012). It seems unlikely that there are direct experiential correlations between suspicion and fishy smells, and harboring secrets and being physically weighed down. We propose that these effects (see also Miles et al., 2010; Schneider et al., 2013) can instead be attributed to metaphor, and that embodied metaphors can, in fact, influence sensorimotor processing.

We argue that by learning an embodied metaphor, sensorimotor states become associated with the abstract concept. According to the SSM model we propose, learning these metaphoric mappings informs and contributes to the development of an abstract concept (as in CMT), but also alters one's representation of the concept, with sensorimotor modalities becoming part of the neural representation of the concept (as in PSS). SSM draws from Damasio's (1989) convergence zone theory, whereby a fast-learning system is distributed across the cortex, with a convergence zone binding diverse aspects of the cortical representation of a concept, and integrating multiple sensorimotor maps and associative areas with bidirectional links (McClelland, McNaughton, & O'Reilly, 1995). Merely conceiving of sensory states leads to modality-specific simulations of those states (Belardinelli et al., 2009), and there are bidirectional links between sensorimotor and higher-order binding areas (Damasio, 1989; McClelland, McNaughton, & O'Reilly, 1995). Thus, learning a new embodied metaphor can link sensorimotor activations to conceptual processing, and therefore sensorimotor modalities that are part of the representation of that concept will activate during conceptual processing (i.e., simulations).[1]

We designed a study to test the predictions this model makes: Participants learned one of two novel metaphors, not based in prior experience, and completed a sensory test. Neither CMT nor PSS would predict an effect of such a manipulation on sensorimotor processing. CMT predicts no influence of conceptual processing upon sensorimotor processing. PSS allows for an influence of conceptual processing upon sensorimotor processing, but such an outcome relies on abstract concepts consisting of multimodal states associated with prior physical experience with the concept. Thus, simply learning a new metaphor, not based in prior physical experience, does not allow for simulations of multimodal states previously physically experienced conjointly with the abstract concept. Alternatively, SSM suggests cross-modal mappings are made when learning a novel embodied metaphor (no prior actual physical experience being necessary as merely conceiving of sensory states leads to modality-specific simulations of those states; Belardinelli et al., 2009). By forming this association between bodily and psychological

[1] SSM shares similarities with Lakoff's (2008) Neural Theory of Metaphor (NTM), but with critical differences. In particular, NTM predicts unidirectional neural projections, whereas SSM is founded upon work demonstrating bidirectional neural projections.

states, sensorimotor processing can become associated with conceptual processing, and they can mutually influence each other. In sum, we examine whether teaching participants *novel* embodied metaphors, *not* based in prior physical experience, can have embodied consequences. Such a finding would not fit either prominent model of embodied cognition (effects are unidirectional in CMT, and PSS suggests prior physical experiential correlations are needed for bidirectional effects), but would meet the predictions of the SSM hypothesis.

## 2. Method

Two hundred undergraduates (52% female) participated in one of eight between-subject conditions, based on random assignment. In all conditions participants were exposed to a novel metaphor concerning weight and time. In four conditions, participants were exposed to the metaphor that the past, relative to the present, was heavy. In the other four conditions, participants were exposed to the metaphor that the present, relative to the past, was heavy. Participants were given a short passage about the self and time, ostensibly written by a philosopher, and were told that their memory for the passage would later be tested. In both passages, participants read sentences such as, "The self is the idea of a unified being which is the source of consciousness. Moreover, this self is the agent responsible for the thoughts and actions of an individual to which they are ascribed." In the "heavy-past" condition, the last sentence read, "The past carries particular weight for who you are today. You must carry your past with you wherever you go." In the "heavy-present" condition, the last sentence read, "The decisions of your past carry no weight. It is your decisions today that define who you are, and you must hold the present with great care."

Subsequently, participants participated in an ostensibly separate study about judging scientific books. They were asked to estimate a book's physical weight (in ounces), how popular the book was in the scientific community (1-*not at all* to 7-*very*) and the book's age (in years). The *metaphor*-factor ("heavy-past," "heavy-present") was crossed by two more factors, *book-age* (old, new), and *exposure* (felt, seen), yielding eight between-subject conditions. In the "old-book" conditions, participants judged a book that appeared to be old, a faded 1984 clothbound hardcover (weighing 52.8 oz.). In the "new-book" conditions, participants judged the same book, except covered with a 2011 dust jacket. In the "felt-book" conditions, participants were physically given the book. In the "seen-book" conditions, participants were provided with a photograph of the book. No participants indicated suspicion of the metaphor induction during debriefing.

We predicted that when handling the "old-book," participants in "heavy-past" condition would judge the book as heavier than participants in the "heavy-present" condition. Conversely, we predicted that when handling the "new-book," participants in the "heavy-present" condition would judge the book as heavier than participants in "heavy-past" condition (see Fig. 1 for the different models' predictions). As we hypothesize that the *opposing* metaphors will have *opposing* effects, we do predict main effects of metaphor, but instead predict and focus on metaphor's interaction with other factors. We predict that the opposing metaphors will influence weight judgments (in opposing ways), but not popularity judgments, when the book is felt (but not when merely seen, suggesting simulation).

## 3. Results

Three participants who handled the "new-book" noticed that the dust jacket did not match the book, and these participants were therefore excluded. A *t*-test confirmed a successful manipulation of apparent book age ($M_{old\text{-}book}$ = 37.48 years, $M_{new\text{-}book}$ = 15.67 years), $t(195) = 5.70$, $p < .001$, $r = .38$. Separate ANOVAs (metaphor × book-age × exposure) were conducted on weight judgments, and popularity judgments.[2]

For perceived popularity, there were no two-way interactions, $Fs < 1.41$, $ps > .23$, $rs < .09$, or three-way interaction, $F(1, 189) = 0.003$, $p = .96$, $r < .01$, demonstrating that metaphors did not have any differential influence upon popularity judgments.

For perceived weight, there was a two-way interaction between metaphor and book-age, $F(1, 189) = 4.23$, $p = .04$, $r = .15$; the remaining two-way interactions were not significant, $Fs < 0.52$, $ps > .47$, $rs < .06$. These effects were qualified, however, by a three-way interaction between metaphor, book-age, and exposure, $F(1, 189) = 7.60$, $p = .006$, $r = .20$. Metaphor therefore had a differential influence upon weight judgments (but not popularity judgments, a proxy for importance; see Jostmann et al., 2009). In alignment with prior work examining simulations of experienced weight (Schneider, Rutjens, Jostmann, & Lakens, 2011), separate follow-up analyses examined seen and felt exposure conditions. Merely seeing a photograph of a book should minimize the possibility of engaging in a simulation of physical weight; yet, seen exposure would not preclude a semantic association between the past and heaviness, for instance, to lead an older book to be judged as heavier (Niedenthal, 2007; Schneider et al., 2011).

For those only *visually exposed* to the book, there was no interaction between metaphor and book-age, *F*(1,

[2] For ease of presentation, we separately report interaction effects for weight judgments, and popularity judgments (in line with predictions for opposing metaphors having interactive effects). Importantly, an initial 2 (metaphor: "heavy-past," "heavy-present") × 2 (book-age: "old-book", "new-book") × 2 (exposure: felt, seen) × 2 (judgment: weight, popularity) mixed-model repeated-measures ANOVA revealed a significant four-way interaction, $F(1, 189) = 5.40$, $p = .02$, $r = .17$. Additionally, there were three other significant effects: a main effect of exposure, $F(1, 189) = 4.97$, $p = .03$, $r = .16$, "felt-books" being judged as more heavy/popular (averaged standardized scores; $M = 0.11$) than "seen-books" ($M = -0.11$), a two-way interaction between judgment and book-age, $F(1, 189) = 44.84$, $p < .001$, $r = .44$, and a three-way interaction between metaphor, book-age and exposure, $F(1, 189) = 5.26$, $p = .02$, $r = .16$. All other effects were non-significant, $Fs < 1.06$, $ps > .30$, $rs < .08$. For perceived popularity, there was a main effect of book-age, $F(1, 189) = 12.38$, $p = .001$, $r = .25$, the "new-book" being rated as more popular within the scientific community ($M = 4.84$) than the "old-book" ($M = 4.09$), but no main effects of metaphor, $F(1, 189) = 0.16$, $p = .69$, $r = .03$, or exposure, $F(1, 189) = 1.64$, $p = .20$, $r = .09$. For perceived weight, there was a main effect of exposure, $F(1, 189) = 20.47$, $p < .001$, $r = .31$, "felt-books" being perceived as heavier ($M = 46.80$ oz.) than "seen-books" ($M = 32.85$ oz.), but no main effects of metaphor, $F(1, 189) = 0.36$, $p = .55$, $r = .04$, or book-age, $F(1, 189) = 0.26$, $p = .61$, $r = .04$.

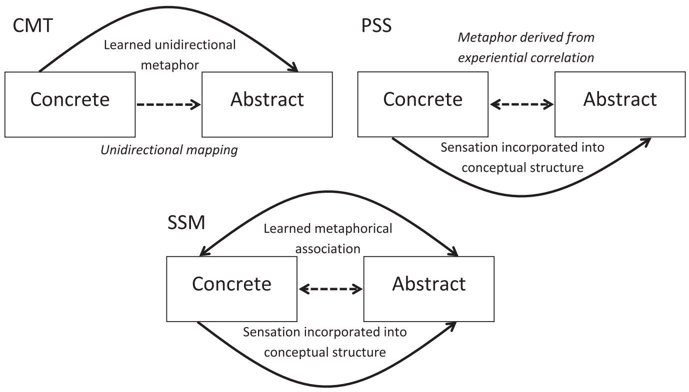


**Fig. 1.** Conceptual Metaphor Theory (CMT), Perceptual Symbol Systems (PSS), and Simulated Sensorimotor Metaphor (SSM) models. Dotted lines indicate direction of influence, and solid lines indicate the building of a metaphor. In CMT, a metaphor is learned or developed by mapping concrete sensation to abstract concepts, allowing sensorimotor processing to influence conceptual processing in this direction only (mappings are not made in the other direction). Thus, learning a metaphor leads sensations to influence conceptual processing. In PSS, an experiential correlation between sensation and abstract concepts leads those sensations (i.e., multimodal states) to be incorporated into the abstract concept's representational structure, with embodied metaphor and bidirectionality as outcomes (i.e., metaphor is an outcome, rather than an input). Thus, bidirectional influences of sensorimotor and conceptual processing result from prior physical correlations between the two. In SSM, due to bidirectional links between sensorimotor and higher-order biding areas made when forming or re-forming a representation of a concept, learning a metaphor leads to incorporation of sensations (i.e., multimodal states) into the concept's representational structure with bidirectional influences. Thus, learning a metaphor can lead to bidirectional effects.

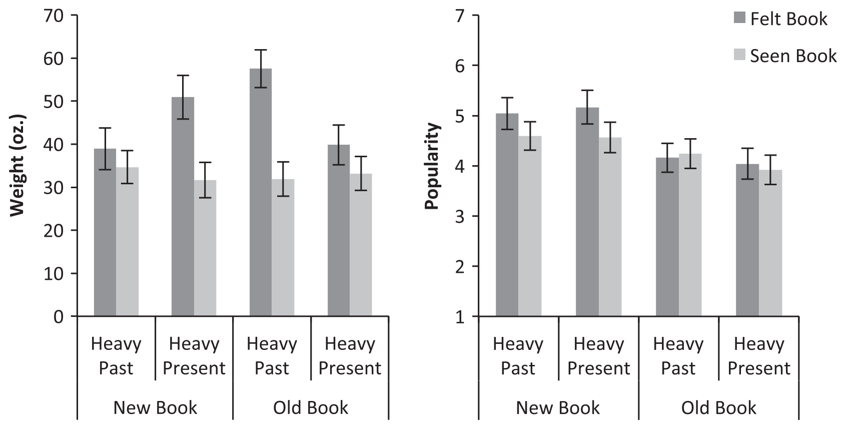


**Fig. 2.** Mean *weight* and *popularity* judgments as a function of *metaphor*, *book-age*, and *exposure*. Error bars denote standard error of the mean.

96) = 0.30, $p = .59$, $r = .06$, whereas this interaction emerged for those who *physically handled* the book, $F(1, 93) = 9.80$, $p = .002$, $r = .31$, suggesting metaphors influenced distinct *embodiments*. Indeed, follow-up *t*-tests demonstrated that when handling the "new-book," participants in the "heavy-present" condition judged the book as heavier ($M$ = 50.90 oz., $SD$ = 24.74) than participants in the "heavy-past" condition ($M$ = 38.91 oz., $SD$ = 11.74), $t(42) = 2.08$, $p = .04$, $r = .31$. When handling the "old-book," participants in the "heavy-past" condition judged the book as heavier ($M$ = 57.53 oz., $SD$ = 32.47) than participants in the "heavy-present" condition ($M$ = 39.84 oz., $SD$ = 16.32), $t(51) = 2.46$, $p = .02$, $r = .33$ (Fig. 2).

## 4. Discussion

In the current work, participants were exposed to novel metaphors regarding time and weight. If exposed to the metaphor that the past is heavy, an object seemingly from the past was perceived as heavier. Yet, precisely the opposite occurred for those exposed to the metaphor that the present is heavy, whereby a book seemingly from the present was perceived as heavier—when the book across all conditions was the same weight. This effect did not emerge when merely seeing an image of a book; the book had to be physically present and experienced, suggesting these results did not occur from mere semantic association (Schneider et al., 2011). Additionally, the results were specific to weight judgments; the metaphor inductions did not influence other conceptually-related judgments (i.e., popularity of the book, a proxy for importance; see Jostmann et al., 2009). Thus, a novel and newly-learned metaphor influenced estimates of physical weight, suggesting embodied simulation (Niedenthal et al., 2007). Possibly, the effects reported here would not be long-lasting, but with repeated exposure to the metaphor, longer-lasting changes to the concept could occur. Moreover, that novel metaphors can be created in the laboratory suggests new methodologies for controlled tests of embodied cognition hypotheses (e.g., accounting for different familiarities with a metaphor, or comparing multiple abstract concepts mapped onto a single sensation). This also raises the possibility of examining the teaching of metaphors not present in one's own language (but present in others), exploring cultural differences in metaphor's influence on sensorimotor processing.

Conceptual Metaphor Theory (CMT) predicts that metaphors for time should not influence sensations of weight because metaphors are unidirectional in mapping concrete sensations to abstract concepts (and not the other direction). As teaching participants a *novel* metaphor, *not* based in prior experience led to embodied simulation, we present findings that do not fit the descriptions of either CMT (as here conceptual processing influenced sensorimotor processing), nor Perceptual Symbol Systems theory (PSS; as the learned metaphor did not originate in physical experience).[3] The current results are consistent with the predictions of an account that combines the mechanisms from both theories, the *Simulated Sensorimotor Metaphor* (SSM) account we propose, which draws from work on neural simulation and learning systems (see Belardinelli et al., 2009; Damasio, 1989; McClelland, McNaughton, & O'Reilly, 1995). This account proposes that learning a metaphor can alter the structure of an abstract concept to include sensorimotor states, allowing for metaphor to influence sensorimotor processing, as demonstrated in the current work. This proposal suggests that metaphors can influence sensorimotor processing, and therefore that embodied metaphors are not restricted to one direction of influence.

The current work also suggests that differences in knowledge of a metaphor might influence embodied outcomes. Despite differences in conceptual metaphors across cultures (Kövecses, 2005; Leung, Qiu, Ong, & Tam, 2011; Núñez & Sweetser, 2006), no work has yet to specifically isolate knowledge of different metaphors as an influence upon sensorimotor processing (cf. IJzerman & Cohen, 2011; Landau et al., 2010). This gap in research might exist because the prominent model of metaphor (CMT) suggests that metaphors, unlike perceptual symbols, cannot influence sensorimotor processing (consequently, only cultural metaphor's influence of sensation upon conceptual processing has been explored; e.g., Boroditsky, Fuhrman, & McCormick, 2011). This has led a number of researchers who have found abstract-to-concrete effects (i.e., influences of conceptual processing on sensorimotor processing) to conclude that those effects are consequences of perceptual symbols, rather than metaphor (e.g., IJzerman & Semin, 2010; Miles et al., 2010; Schneider et al., 2011; Slepian et al., 2012). Yet here we present experimental evidence that specifically isolates metaphor as an influence upon sensorimotor processing by specifically introducing novel metaphors. Prior bidirectional effects hypothesized as originating from perceptual symbols could be revisited as metaphor may still provide a viable model for such effects.

The current work aligns with another recent examination of metaphor's influence upon sensorimotor processing. Lee and Schwarz (2012) found that suspicion ("something smells fishy") led to an enhanced ability to detect fishy smells. They proposed that a unidirectional metaphor could produce bidirectional effects due to the dynamic online interaction between sensorimotor and conceptual processing. SSM is in alignment with this possibility, but focuses not on online processing, but instead representational structure, drawing on models of learning systems to propose a model of metaphor acquisition. Both theories suggest refinements to current thinking on embodied metaphor, but at different levels, process and structure. We suggest future work exploring this distinction could bring insights to models of embodied cognition.

The current work demonstrates that novel embodied metaphors can be learned in the laboratory and have embodied effects. An interesting question that remains is whether *any* metaphorical mapping can be introduced in the laboratory, or whether only certain metaphorical mappings might hold. Perhaps only embodied metaphors that are scaffolded upon *image schemas*—non-linguistic analogues of patterned bodily interaction with the external world—can be learned (Lakoff & Johnson, 1980; Schnall, 2013). For example, because of gravity, when something accumulates it tends to accumulate upward (along our vertical bodily dimension; i.e., "more is up"). This image schema might underlie many metaphors (e.g., "(more) good is up," "(more) moral is up). Given that taller things tend to have greater mass, and thus weight, building on these might be "(more) important is weighty," and novelly, "(more) past/present is weighty."[4] The introduction of a novel embodied metaphor that does not rely upon an image schema may be less likely to have embodied consequences. Future research could explore this possibility. In sum, metaphors can be learned in the laboratory through language and communication and have sensorimotor consequences. We suggest that a fruitful method for examining the origins and mechanisms of embodied effects might be creating them in the laboratory.

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[3] PSS includes a theorized "introspective simulation" component, which could be interpreted as encompassing the learning of metaphors. This possibility is not explicitly outlined in PSS, however, which is the goal of SSM.

[4] Interestingly, similar to other metaphors, weight metaphors have polarity differences (see Lakens, 2012). For example, weighty is the default polar-endpoint, rather than lightness (i.e., "less weighty" is preferred over "more lightness"). Future work could systematically introduce metaphors with and without polarity differences to explore their role in embodied effects.

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