Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Psychology

Multimodal priming of abstract constructs

Spike WS Lee

Abstract constructs such as morality, warmth, and competence are the bread and butter of social psychology. Their antecedents and consequences have been explored frequently using semantic priming, in keeping with early models of memory representation as a semantic network of concept nodes. Contrary to what these models would predict, sensorimotor experiences in multiple modalities have proven capable of activating abstract constructs, even if they are no more than metaphorically related. In this paper, I review illustrative evidence for multimodal priming of abstract constructs through embodied metaphors. This work has implications for debates about the activation of mental content and the form of mental representation. It also highlights the need to address several thorny issues for theoretical advances.

Address
University of Toronto, Canada

Corresponding author: Lee, Spike W.S. (spike.lee@utoronto.ca)

Current Opinion in Psychology 2016, **12**:37–44

This review comes from a themed issue on **Social priming**

Edited by **Fritz Strack** and **Norbert Schwarz**

http://dx.doi.org/10.1016/j.copsyc.2016.04.016

Social psychologists entertain abstract constructs. Morality, warmth, competence, power, valence — all are meaningful yet not very imageable; they are applicable across various instantiations rather than tied to fixed manifestations [1–4]. To study their antecedents and consequences, priming has become a standard method [5], thanks to the importation of influential cognitive paradigms into social psychology in the 1970s. In its most basic sense, 'priming refers to procedures that stimulate or activate some stored knowledge' [6, p. 134]. This raises two fundamental questions: (1) What procedures can stimulate or activate abstract constructs? (2) How are these abstract constructs stored or represented?

Semantic vs. multimodal priming of abstract constructs

How abstract constructs are activated depends partly on how they are represented. Early models conceptualize memory representation as a semantic network of concept nodes. To activate a node, one needs to stimulate it, or its associated nodes (from which activation spreads [7]), using semantic stimuli, which were presented mostly in linguistic forms in social psychology, like trait terms [8] or stereotypical concepts [9]. This approach gained tremendous momentum, with countless studies attesting to the consequences of semantic priming [6,10–12].

But does the activation of abstract constructs require linguistic, semantic primes? Or can they be primed by something non-linguistic and much more basic, like low-level sensorimotor cues of perceptual experience? Classic views on priming would predict not, given the dissociation of perceptual representation from semantic and other memory systems [13]. Contrary to this prediction, numerous basic sensorimotor manipulations have been shown to activate abstract constructs [14••]. Because sensorimotor experiences in multiple modalities (e.g., tactile, olfactory, gustatory) can function as effective primes, I call this process *multimodal priming* of abstract constructs.

How can multimodal experiences activate abstract constructs? Through embodied metaphors, according to a rapidly growing body of experimental evidence. To understand this process, two common confusions require clarification.

Conceptual vs. linguistic metaphor

By metaphor, I mean conceptual metaphor, not linguistic metaphor. 'The essence of [conceptual] metaphor is understanding and experiencing one kind of thing in terms of another' [15, p. 5] such that 'metaphorical entailments can characterize a coherent system of metaphorical concepts and a corresponding coherent system of metaphorical expressions for those concepts' [p. 9]. A linguistic metaphor is the surface-level manifestation of a deeper conceptual system of 'cross-domain mapping' [16, p. 203], typically from sensorimotor experiences (e.g., clean, warm) to abstract constructs (e.g., moral, affectionate).

Empirically, to study a linguistic metaphor, it obviously has to be present in language. But a conceptual metaphor — if it really exists in the conceptual system — can exert its influence without language [17], through sensorimotor cues like touch, taste, smell, sound, location, and movement [14••]. A conceptual metaphor lends itself to multimodal priming.

Metaphorical vs. nonmetaphorical

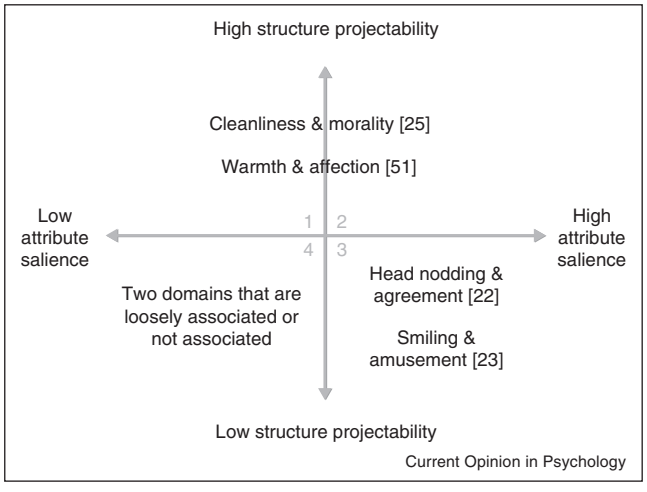
A metaphorical relation involves cross-domain mapping; a direct, nonmetaphorical relation involves within-domain mapping [15,18,19]. This distinction appears easy

enough. But what circumscribes a domain is vague, subjective, context-dependent. For example, physics and biology are different domains of science. But in the context of university structure, they may fall within the same domain of natural sciences, as opposed to social sciences. And natural and social sciences may be jointly considered in the broad domain of sciences, as opposed to arts. A domain's scope is anything but fixed.

So how do we tell if two things are in the same or different domains, 'directly' or 'metaphorically' related? I propose a two-dimensional space for characterizing different psychological relations between a bodily domain and an abstract domain (Figure 1). One dimension reflects the extent to which people find the bodily domain's relational/inferential structure to be projectable to the abstract domain. Another dimension reflects the extent to which people find the bodily domain to be a salient attribute of the abstract domain.

Both dimensions — structure projectability and attribute salience — are continuous, conceptual, subjectively construed, and context-sensitive parameters. They are continuous, not categorical, in that metaphorical and nonmetaphorical relations vary on a continuum rather than constitute two clear-cut categories. They are conceptual, not linguistic, insofar as linguistic patterns only inform but do not determine conceptual relations. They are subjectively construed and context-sensitive, not objectively out there and fixed across contexts, because which object-attributes are salient and which relational/inferential structures are projectable depend on the person and the situation. It is tempting to think that the projectability of relational/inferential structures across domains is an objective fact, an observer-independent aspect of reality. It is not, because any two domains share an infinite number of features and between-features relations/inferences. Projectability is thus not a parameter of what is objectively projectable, which is logically intractable. Projectability is a parameter of what people find subjectively projectable in specific contexts, which is psychologically tractable, for example, by assessing how many features, relations, and inferences of one domain people spontaneously use in reasoning about another domain, or how easily or fluently they do so.

Figure 1



A two-dimensional space, with examples, for characterizing different psychological relations between a bodily domain and an abstract domain. Structure projectability reflects the extent to which people find the bodily domain's relational/inferential structure to be projectable to the abstract domain. Attribute salience reflects the extent to which people find the bodily domain to be a salient attribute of the abstract domain.

In this two-dimensional space, we see four quadrants of effects; these are simplifications of course, given the continuous dimensions. If structure projectability is high, the bodily domain is likely to metaphorize the abstract domain, whether it is a salient attribute of the abstract domain (quadrant 2) or not (quadrant 1). Multimodal primes in the bodily domain should produce full-blown, multifaceted effects on the abstract domain, that is, embodied metaphorical effects. For example, the relational/inferential structure of bodily disgust (e.g., contamination, purification, rejection) is highly projectable to moral intuition, even though it is a more salient attribute of sexual morality (quadrant 2) than of nonsexual morality (quadrant 1), so disgust exerts embodied metaphorical effects on moral judgments across sexual and nonsexual issues [20,21].

If structure projectability is low, the bodily domain is unlikely to metaphorize the abstract domain. Still, nonmetaphorical effects may result from manipulating the bodily domain if it is a salient attribute of the abstract domain (quadrant 3). For example, head nodding is a salient attribute of mental agreement, so incidental activation of head nodding increased people's agreement with persuasive messages [22]. While bodily activation of a salient attribute increases its effect, bodily inhibition decreases its effect. For example, smiling is a salient attribute of affective amusement, so unobtrusively inhibiting the facial muscles responsible for smiling decreased amusement with cartoons [23].

If both structure projectability and attribute salience are low (quadrant 4), no effect is expected.

Multimodal priming of abstract constructs through embodied metaphors

Experimental work on embodied metaphors has grown rapidly in the past 10 years. It shows that sensorimotor cues prime abstract constructs to produce coherent systems of metaphorical effects. Conversely, processing abstract constructs changes metaphorically related sensorimotor experience in multiple modalities [24•]. For example, given the metaphorical relation between cleanliness and morality,

physical cleansing reduced moral guilt from past transgressions [25••] and moral condemnation [26]. Conversely, recalling one's immoral (vs. moral) experience activated cleansing-related thoughts [25••].

Supporting the role of modality in multimodal priming, moral cleanliness has shown modality-specific effects: After doing something immoral with their hands, people favored hand sanitizer, but after doing something immoral with their mouth, they favored mouthwash [27; see also 28]. Effects of moral cleanliness thus appear strongest on whichever modality is momentarily salient. They also appear strongest on whichever modality is chronically salient: In a face culture, where the facial modality has sociomoral significance and chronic salience, immoral behavior specifically potentiates desires for a face-cleaning product and increases spontaneous face-cleaning behavior [29].

Numerous sensorimotor cues across modalities have been found to produce metaphorical effects (Table 1). Tactile and kinesthetic experiences of warm vs. cold, smooth vs. rough, and heavy vs. light elicit changes consistent with their metaphorically related abstract constructs of affectionate vs. aloof, agreeable vs. disagreeable, and important vs. unimportant. Olfactory and gustatory cues of fishy, clean, bitter, and sweet evoke suspicion, morality, condemnation, and agreeableness. Visual cues of spatial distance, font size, and vertical location influence judgments of temporal duration, psychological distance, conceptual similarity, social power, valence, divinity, and rationality. Motor and interoceptive cues of approach vs. avoidance, forward vs. backward, and firm vs. loose activate or facilitate processing of transfer of ideas toward vs. away from oneself, good vs. bad memory, future vs. past, and strong vs. weak self-control.

As is typical in stage 1 of the scientific cycle (*loosening*), effects abound after a decade of prolific experimentation, but are open to different interpretations. These deserve attention [30,31], together with a few thorny issues identified below, as we enter stage 2 (*tightening*) now.

Thorny issues

'One-to-many' problem

Most experiments have focused on one-to-one mapping between a sensorimotor cue and an abstract construct. What about cases where one sensorimotor cue has metaphorical relations to many abstract constructs? For example, verticality (up) primes such diverse meanings as good, happy, powerful, dominant, divine, moral, and rational (Table 1). Why is one bodily domain metaphorically related to multiple abstract domains? Is it because there are far more abstract meanings our minds can comprehend than physical states our bodies can actualize [15,32] so some bodily experiences get recruited to scaffold many abstract meanings?

If so, a given sensorimotor cue may prime several abstract constructs, and which of them exerts influence on an outcome should depend on personal and situational factors. For example, if a task requires attention to one abstract construct (e.g., power) over another (e.g., valence), then a sensorimotor cue (e.g., up) is more likely to exert influence through the attended than the unattended construct [33]. A sensorimotor cue (e.g., clean) is also more likely to exert influence through an abstract construct that is chronically accessible (e.g., face [29,34]). I suspect traditional principles of knowledge activation and use (e.g., accessibility, applicability, salience [6]) may characterize multimodal priming effects in context [24•]. This context-sensitive view may shed light on ways to resolve the one-to-many problem in embodied metaphorical effects.

Explanations for multimodal priming

Theoretical predictions about moderating variables are emerging [24•,35–37]. Testing them with facilitatory and inhibitory paradigms holds promise for revealing proximal mechanisms underlying multimodal priming. In so doing, what look like different effects may be unified by a single mechanism; what look like the same effect may be mediated by multiple mechanisms, in which case they can be teased apart by testing their signature predictions against each other.

For example, if an embodied metaphorical effect occurs by activating goals (vs. concepts), then it should increase (vs. decrease) with time, because unsatisfied goals become more motivating over time, whereas concepts become less accessible over time [38]. If an embodied metaphorical effect is driven by feelings-as-information, then it should be weakened by attributing the bodily feeling to a plausible source, because attribution undermines the feeling's informative value [39].

Beyond these proximal mechanisms, developmental, evolutionary, and functional explanations [40] for multimodal priming remain crude and need fleshing out [41••,42,43].

How are abstract constructs represented?

Seeing how many abstract constructs are primeable by multiple sensorimotor modalities, it is tempting to assume that abstract constructs are *represented* in multiple sensorimotor modalities [18]. The evidence is compatible with, but does not lend unequivocal support to, this strong claim.

Consider three perspectives on cognition (Figure 2). In the traditional view of semantic priming (perspective 1), linguistic or pictorial stimuli activate knowledge, which is represented in a semantic network of amodal symbols, with spreading activation from one node to another. In the weak embodied view of multimodal priming (perspective

Table 1

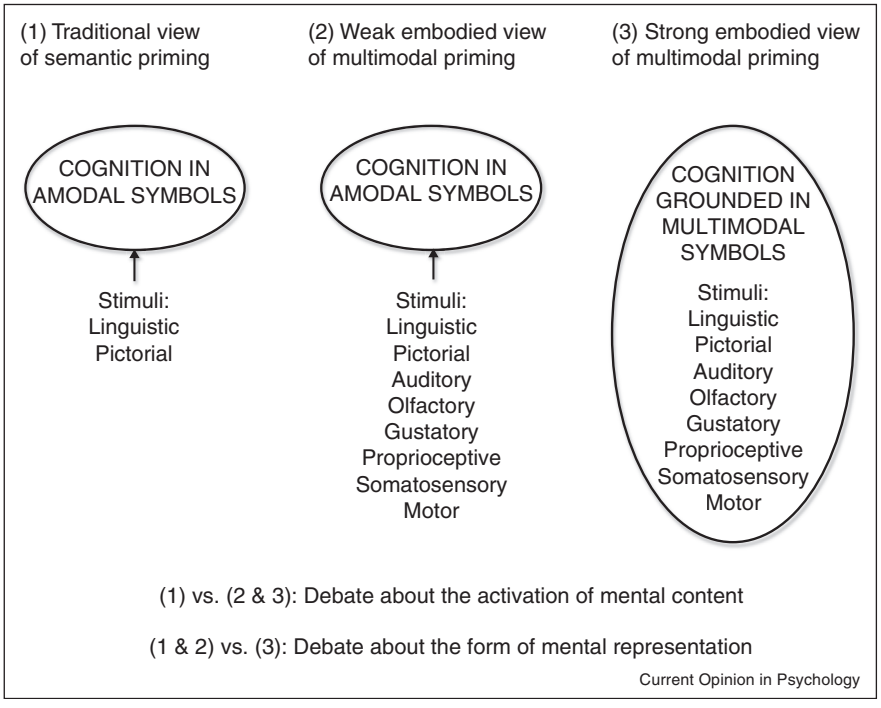
Examples of multimodal priming of abstract constructs through embodied metaphors.

Modality	Manipulation	Effect	Citation
Tactile	Briefly holding a warm (vs. cold) beverage or therapeutic pack	Increases perception of a target as interpersonally warm; increases likelihood of making a prosocial choice	Williams and Bargh [51]
Tactile	Briefly holding a warm (vs. cold) beverage or being in warm (vs. cold) temperatures	Increases the sense of interpersonal overlap	IJzerman and Semin [52]
Tactile	Briefly holding a warm (vs. cold) therapeutic pack	Increases monetary investment in a trust game	Kang et al. [53]
Tactile	Playing a puzzle with rough (vs. smooth) pieces	Increases perception of a social interaction as difficult and adversarial; increases monetary offers in an ultimatum game	Ackerman et al. [54]
Tactile	Touching rough sandpaper (vs. smooth paintbrush)	Increases perception of a social interaction as difficult and adversarial, which is strongly associated with activation of somatosensory brain regions	Schaefer et al. [55]
Kinesthetic	Filling out a survey presented on a heavy (vs. light) clipboard	Increases judged importance of information in the survey; increases elaborate processing of the information	Jostmann et al. [56]; Ackerman et al. [54]
Kinesthetic	Carrying a heavy (vs. light) shopping bag	Increases judged importance of information in the survey	Zhang and Li [57]
Kinesthetic	Filling out a survey presented on a heavy (vs. light) clipboard	Increases judged importance of information in the survey, especially if it concerns a near (vs. far) event	Maglio and Trope [58]
Kinesthetic	Inserting concealed weight into a book	Increases judged importance of the book if people have enough knowledge to form a judgment about it	Chandler et al. [59]
Kinesthetic	Inserting concealed weight into a book	Increases judged importance of the book if people have done enough thinking about it	Hauser and Schwarz [60]
Kinesthetic	Holding a heavy (vs. light) clipboard	Increases estimated seriousness of diseases and estimated effectiveness of drugs	Kaspar [61]
Kinesthetic	Holding a heavy (vs. light) clipboard or heavy (vs. light) pillow boxes	Increases judgment of one's own learning of information	Alban and Kelley [62]
Olfactory	Incidental exposure to fishy (vs. non-fishy bad or neutral) smells	Decreases monetary investment in a trust game or a public goods game	Lee and Schwarz [24•]
Olfactory	Incidental exposure to fishy (vs. neutral) smells	Increases sensitivity in detecting trick questions; increases performance on Wason rule discovery task	Lee et al. [63]
Olfactory	Clean scents (vs. no scent) in a room	Increase moral behaviors such as reciprocating money and volunteering time	Liljenquist et al. [64]
Gustatory	Bitter (vs. sweet or neutral) tastes	Increase gustatory disgust response and moral condemnation, especially among conservatives	Eskine et al. [65]
Gustatory	Both bitter tastes and immoral behaviors	Increase activation of facial muscles responsible for oral-nasal rejection (levator labii)	Chapman et al. [66]
Gustatory	Sweet (vs. nonsweet) tastes	Increase self-reported agreeableness and helping behavior ('sweeter personalities')	Meier et al. [31]
Gustatory	Sweet (vs. nonsweet) tastes	Increase favorable evaluation of hypothetical relationships and interest in initiating a romantic relationship	Ren et al. [67]
Visual	Seeing lines grow in length to be much (vs. a little) longer within a fixed amount of time	Increases judgment of their duration on screen	Casasanto and Boroditsky [17]
Visual	Marking off two points that are far apart (vs. moderately apart or close together) on a paper grid	Decreases strength of social bonds with one's family and hometown; decreases estimated caloric content in unhealthy food; decreases negative affect from reading a violent story; increases enjoyment of an embarrassing story	Williams and Bargh [51]
Visual	Seeing two abstract nouns presented far apart (vs. close together)	Decreases judgment of their similarity	Casasanto [68]

Table 1 (*Continued*)

Modality	Manipulation	Effect	Citation
Visual	Seeing big (vs. small) font sizes	Increases speed and accuracy of judging groups as powerful (vs. powerless)	Schubert et al. [69]
Visual	Seeing powerful groups presented at the top (vs. bottom) and powerless groups at the bottom (vs. top) of the screen	Increases speed of finding both groups and judging their power	Schubert [70]
Visual	Seeing an organizational chart with greater (vs. less) vertical separation between the manager and subordinates	Increases judgment of the manager's leader power	Giessner and Schubert [71]
Visual	Seeing positive words presented at the top (vs. bottom) and negative words at the bottom (vs. top) of the screen	Increases speed of evaluating their valence	Meier and Robinson [72]
Visual	Seeing God-related words presented at the top (vs. bottom) of the screen	Increases speed of categorizing them as related to God rather than to the Devil	Meier et al. [73]
Visual	Seeing unfamiliar stimuli (Chinese characters) presented at the top (vs. bottom) of the screen	Increases judgment of Chinese characters as fitting for a statistical website, which has rational connotations (vs. a dating website, which has emotional connotations)	Cian et al. [74]
Motor & intero-ceptive	Moving index finger from a middle to a close (vs. far) key	Increases speed of judging sensibility of sentences that describe abstract transfer of ideas toward (vs. away from) oneself	Glenberg and Kaschak [75]
Motor & intero-ceptive	Moving marbles upwards (vs. downwards)	Increases speed of retelling and amount of retrieval of positive (vs. negative) memories	Casasanto and Dijkstra [76]
Motor & intero-ceptive	Forward (vs. backward) spatial movement	Increases judgment of proximity of three weeks in the future (vs. past)	Caruso et al. [77]
Motor & intero-ceptive	Firming one's muscles (e.g., hand, calf, biceps)	Increases behaviors that require firming one's willpower (e.g., donating money to an unpleasant charity appeal, drinking a healthy by awful-tasting tonic)	Hung and Labroo [78]

Figure 2



Three perspectives on cognition (denoted by the ellipse), varying on how abstract constructs are activated (by what stimuli) and represented (in what form).

2), multiple sensorimotor modalities are channels for activating knowledge, which is still represented as amodal symbols but associated with sensorimotor processes [42]. In the strong embodied view of multimodal priming (perspective 3), multiple sensorimotor modalities are used in simulating knowledge, which is represented in sensorimotor systems [41••], and metaphors predict which abstract constructs are grounded in which sensorimotor activities [15,18].

Multimodal priming is predicted a priori by perspectives 2 and 3, but not 1 (unless post hoc assumptions are added). As such, the evidence favors perspectives 2 and 3 but does not distinguish between them. Hybrid perspectives involving both amodal and modal representations have also been offered [44••] but lack parsimony.

Evidence of multimodal priming, when considered in conjunction with other issues, nudges me toward the strong embodied view (perspective 3). First, it predicts that linguistic and motoric processes influence each other, as borne out by social and cognitive experiments [9,45–50]. Second, it resolves the symbol grounding problem [44••]; the other perspectives do not. Third, it assumes cognitive representation in sensorimotor systems, for which there is neural evidence, whereas the other perspectives assume the existence of an additional layer of mental representation (amodal symbols), for which there is no clear evidence [41••].

While these considerations are important in their own right, they are not incompatible with social psychologists' concern with contextual influences on thinking, feeling, and doing, which motivated social priming research. As far as this is concerned, the reviewed work unequivocally shows that diverse sensorimotor experiences in multiple modalities can prime abstract constructs of social interest.

Acknowledgements

I acknowledge generous support by the Social Sciences and Humanities Research Council and the Connaught New Researcher Award while preparing this article. I also thank the anonymous reviewer and guest editors for insightful and helpful comments.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Strack F, Schwarz N, Gschneidinger E: **Happiness and reminiscing: the role of time perspective, affect, and mode of thinking**. *J Pers Soc Psychol* 1985, **49**:1460-1469.

2. Semin GR, Fiedler K: **The linguistic category model, its bases, applications and range**. *Eur Rev Soc Psychol* 1991, **2**:1-30.

3. Trope Y, Liberman N: **Temporal construal**. *Psychol Rev* 2003, **110**:403-421.

4. Casasanto D: **Embodiment of abstract concepts: good and bad in right- and left-handers**. *J Exp Psychol Gen* 2009, **138**:351-367.

5. Bargh JA, Chartrand TL: **The mind in the middle: a practical guide to priming and automaticity research**. In *Handbook of Research Methods in Social and Personality Psychology*. Edited by Reis HT, Judd CM.. Cambridge University Press; 2000:253-285.

6. Higgins ET: **Knowledge activation: accessibility, applicability, and salience**. In *Social Psychology: Handbook of Basic Principles.* Edited by Higgins ET, Kruglanski AW. Guilford Press; 1996:133-168.

7. Collins AM, Loftus EF: **A spreading-activation theory of semantic processing**. *Psychol Rev* 1975, **82**:407-428.

8. Higgins ET, Rholes WS, Jones CR: **Category accessibility and impression formation**. *J Exp Soc Psychol* 1977, **13**:141-154.

9. Bargh JA, Chen M, Burrows L: **Automaticity of social behavior: direct effects of trait construct and stereotype activation on action**. *J Pers Soc Psychol* 1996, **71**:230-244.

10. Bargh JA, Ferguson MJ: **Beyond behaviorism: on the automaticity of higher mental processes**. *Psychol Bull* 2000, **126**:925-945.

11. Wheeler SC, Petty RE: **The effects of stereotype activation on behavior: a review of possible mechanisms**. *Psychol Bull* 2001, **127**:797-826.

12. Loersch C, Payne BK: **The situated inference model: an integrative account of the effects of primes on perception, behavior, and motivation**. *Perspect Psychol Sci* 2011, **6**:234-252.

13. Tulving E, Schacter D: **Priming and human memory systems**. *Science* 1990, **247**:301-306.

14. •• Landau MJ, Robinson MD, Meier BP: **The power of metaphor: examining its influence on social life**. *Am Psychol Assoc* 2014.
This book contained contributions from social, personality, and cognitive psychologists. They reviewed the burgeoning research on embodied metaphors and their pervasive influence on memory, thought, action, emotion, judgment, and decision making. Effects are manifest in contexts of culture, morality, politics, intergroup relations, and public opinion.

15. Lakoff G, Johnson M: *Metaphors We Live By*. The University of Chicago Press; 1980.

16. Lakoff G: **The contemporary theory of metaphor**. In *Metaphor and Thought.* Edited by Ortony A. Cambridge University Press; 1993:202-251.

17. Casasanto D, Boroditsky L: **Time in the mind: using space to think about time**. *Cognition* 2008, **106**:579-593.

18. Lakoff G, Johnson M: *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought. Basic Books*. 1999.

19. Landau MJ, Meier BP, Keefer LA: **A metaphor-enriched social cognition**. *Psychol Bull* 2010, **136**:1045-1067.

20. Schnall S, Haidt J, Clore GL, Jordan AH: **Disgust as embodied moral judgment**. *Pers Soc Psychol Bull* 2008, **34**:1096-1109.

21. Chapman HA, Anderson AK: **Things rank and gross in nature: a review and synthesis of moral disgust**. *Psychol Bull* 2013, **139**:300-327.

22. Wells GL, Petty RE: **The effects of overt head movements on persuasion: compatibility and incompatibility of responses**. *Basic Appl Soc Psychol* 1980, **1**:219-230.

23. Strack F, Martin LL, Stepper S: **Inhibiting and facilitating conditions of the human smile: a nonobtrusive test of the facial feedback hypothesis**. *J Pers Soc Psychol* 1988, **54**:768-777.

24. • Lee SWS, Schwarz N: **Bidirectionality, mediation, and moderation of metaphorical effects: the embodiment of social suspicion and fishy smells**. *J Pers Soc Psychol* 2012, **103**:737-749.
This paper applied the social cognitive principles of knowledge activation and use to embodied metaphorical effects. It argued that contrary to common assumptions, metaphorical effects should run bidirectionally between bodily states and abstract constructs (e.g., clean <-> morality, fishy <-> suspicion). It predicted that metaphorical effects are mediated by the accessibility of metaphorically associated concepts and moderated by their applicability in context.

25. Zhong CB, Liljenquist K: **Washing away your sins: threatened morality and physical cleansing**. *Science* 2006, **313**:1451-1452.
•• This empirical paper reported four elegant experiments demonstrating that threats to the moral self elicited thoughts about and desires for physical cleansing and that physical cleansing weakened the emotional and behavioral impact of threats to the moral self. It sparked interest in moral cleansing and many other embodied metaphors.

26. Schnall S, Benton J, Harvey S: **With a clean conscience: cleanliness reduces the severity of moral judgments**. *Psychol Sci* 2008, **19**:1219-1222.

27. Lee SWS, Schwarz N: **Dirty hands and dirty mouths: embodiment of the moral-purity metaphor is specific to the motor modality involved in moral transgression**. *Psychol Sci* 2010, **21**:1423.

28. Denke C, Rotte M, Heinze HJ, Schaefer M: **Lying and the subsequent desire for toothpaste: activity in the somatosensory cortex predicts embodiment of the moral-purity metaphor**. *Cereb Cortex* 2014, **24**:1-8.

29. Lee SWS, Tang H, Wan J, Mai X, Liu C: **A cultural look at moral purity: wiping the face clean**. *Front Psychol* 2015, **6**:577.

30. Fiedler K: **On embodied cognition and mental simulation: a meta-theoretical comment to Zwaan's treatise**. *Eur J Soc Psychol* 2009, **39**:1156-1159.

31. Meier BP, Schnall S, Schwarz N, Bargh JA: **Embodiment in social psychology**. *Top Cogn Sci* 2012, **4**:705-716.

32. Maass A: **Culture's two routes to embodiment**. *Eur J Soc Psychol* 2009, **39**:1290-1293.

33. Schubert TW: **Your highness: vertical position as perceptual symbols of power**. *J Pers Soc Psychol* 2005, **89**:1-21.

34. Cohen D, Leung AKY: **The hard embodiment of culture**. *Eur J Soc Psychol* 2009, **39**:1278-1289.

35. Lee SWS, Schwarz N: **Metaphor in judgment and decision making**. In *The Power of Metaphor: Examining Its Influence on Social Life.* Edited by Landau MJ, Robinson MD, Meier BP. American Psychological Association; 2014:85-108.

36. Körner A, Topolinski S, Strack F: **Routes to embodiment**. *Front Psychol* 2015, **6**:940.

37. Lee SWS, Schwarz N: **Clean-moral effects and clean-slate effects: physical cleansing an as embodied procedure of psychological separation**. In *Purity and Danger Now: New Perspectives.* Edited by Duschinsky R, Schnall S, Weiss D. 2016.

38. Förster J, Liberman N, Friedman RS: **Seven principles of goal activation: a systematic approach to distinguishing goal priming from priming of non-goal constructs**. *Pers Soc Psychol Rev* 2007, **11**:211-233.

39. Schwarz N, Clore GL: **Feelings and phenomenal experiences**. In *Social Psychology: Handbook of Basic Principles*, 2007. Edited by Kruglanski AW, Higgins ET. Guilford Press; 2007:385-407.

40. Tinbergen N: **On aims and methods of ethology**. *Z Tierpsychol* 1963, **20**:410-433.

41. Barsalou LW: **Perceptual symbol systems**. *Behav Brain Sci* 1999, **22**:577-660.
•• This paper rejected prevailing amodal theories of cognition and proposed a formal perceptual theory of knowledge and thought for cognitive science and neuroscience. It sparked a vigorous debate about the role of perceptual processes like bodily states in cognitive functions like abstract thought.

42. Williams LE, Huang JY, Bargh JA: **The scaffolded mind: higher mental processes are grounded in early experience of the physical world**. *Eur J Soc Psychol* 2009, **39**:1257-1267.

43. Anderson ML: **Neural reuse: a fundamental organizational principle of the brain**. *Behav Brain Sci* 2010, **33**:245-266.

44. Harnad S: **The symbol grounding problem**. *Phys D* 1990, **42**: 335-346.
•• This paper highlighted a fundamental problem of purely symbolic models of the mind. The problem is that amodal symbols, which are arbitrary tokens, by themselves cannot give rise to any meaning. They have to be grounded in nonsymbolic representations. This problem is resolved by embodied models to the extent that they ground abstract constructs in nonsymbolic, nonarbitrary bodily states.

45. Chen M, Bargh JA: **Consequences of automatic evaluation: immediate behavioral predispositions to approach or avoid the stimulus**. *Pers Soc Psychol Bull* 1999, **25**:215-224.

46. Tucker M, Ellis R: **On the relations between seen objects and components of potential actions**. *J Exp Psychol Hum* 1998, **24**:830-846.

47. Creem SH, Proffitt DR: **Grasping objects by their handles: a necessary interaction between cognition and action**. *J Exp Psychol Hum* 2001, **27**:218-228.

48. Glover S, Dixon P: **Semantics affect the planning but not control of grasping**. *Exp Brain Res* 2002, **146**:383-387.

49. Pulvermüller F, Shtyrov Y, Ilmoniemi R: **Brain signatures of meaning access in action word recognition**. *J Cogn Neurosci* 2005, **17**:884-892.

50. Zwaan RA, Taylor LJ: **Seeing, acting, understanding: motor resonance in language comprehension**. *J Exp Psychol Gen* 2006, **135**:1-11.

51. Williams LE, Bargh JA: **Experiencing physical warmth promotes interpersonal warmth**. *Science* 2008, **322**:606-607.

52. IJzerman H, Semin GR: **The thermometer of social relations: mapping social proximity on temperature**. *Psychol Sci* 2009, **20**:1214-1220.

53. Kang Y, Williams LE, Clark MS, Gray JR, Bargh JA: **Physical temperature effects on trust behavior: the role of insula**. *Soc Cogn Affect Neurosci* 2010, **6**:507-515.

54. Ackerman JM, Nocera CC, Bargh JA: **Incidental haptic sensations influence social judgments and decision**. *Science* 2010, **328**:1712-1715.

55. Schaefer M, Denke C, Heinze H-J, Rotte M: **Rough primes and rough conversations: evidence for a modality-specific basis to mental metaphors**. *Soc Cogn Affect Neurosci* 2013 http://dx.doi.org/10.1093/scan/nst163.

56. Jostmann NB, Lakens D, Schubert TW: **Weight as an embodiment of importance**. *Psychol Sci* 2009, **20**:1169-1174.

57. Zhang M, Li X: **From physical weight to psychological significance: the contribution of semantic activations**. *J Consum Res* 2012, **38**:1063-1075.

58. Maglio SJ, Trope Y: **Disembodiment: abstract construal attenuates the influence of contextual bodily state in judgment**. *J Exp Psychol Gen* 2012, **141**:211-216.

59. Chandler JJ, Reinhard D, Schwarz N: **To judge a book by its weight you need to know its content: knowledge moderates the use of embodied cues**. *J Exp Soc Psychol* 2012, **48**:948-952.

60. Hauser DJ, Schwarz N: **Elaborative thinking increases the impact of physical weight on importance judgments**. *Soc Cognition* 2015 http://dx.doi.org/10.1521/soco.2015.33.2.120.

61. Kaspar K: **A weighty matter: heaviness influences the evaluation of disease severity, drug effectiveness, and side effects**. *PLoS ONE* 2013, **8**:e78307.

62. Alban MW, Kelley CM: **Embodiment meets metamemory: weight as a cue for metacognitive judgments**. *J Exp Psychol Learn Mem Cogn* 2013, **39**:1628-1634.

63. Lee DS, Kim E, Schwarz N: **Something smells fishy: olfactory suspicion cues improve performance on the Moses illusion and Wason rule discovery task [Internet]**. *J Exp Soc Psychol* 2015 http://dx.doi.org/10.1016/j.jesp.2015.03.006.

64. Liljenquist K, Zhong C-B, Galinsky AD: **The smell of virtue: clean scents promote reciprocity and charity**. *Psychol Sci* 2010, **21**:381-383.

65. Eskine KJ, Kacinik NA, Prinz JJ: **A bad taste in the mouth: gustatory disgust influences moral judgment**. *Psychol Sci* 2011, **22**:295-299.

66. Chapman HA, Kim DA, Susskind JM, Anderson AK: **In bad taste: evidence for the oral origins of moral disgust**. *Science* 2009, **323**:1222-1226.

67. Ren D, Tan K, Arriaga XB, Chan KQ: **Sweet love: the effects of sweet taste experience on romantic perceptions**. *J Soc Pers Relat* 2015, **32**:905-921.

68. Casasanto D: **Similarity and proximity: when does close in space mean close in mind?** *Mem Cognit* 2008, **36**:1047-1056.

69. Schubert TW, Waldzus S, Giessner SR: **Control over the association of power and size**. *Soc Cognition* 2009, **27**:1-19.

70. Schubert TW: **Your highness: vertical positions as perceptual symbols of power**. *J Pers Soc Psychol* 2005, **89**:1-21.

71. Giessner SR, Schubert TW: **High in the hierarchy: how vertical location and judgments of leaders' power are interrelated**. *Organ Behav Hum Decis Process* 2007, **104**:30-44.

72. Meier BP, Robinson MD: **Why the sunny side is up**. *Psychol Sci* 2004, **15**:243-247.

73. Meier BP, Hauser DJ, Robinson MD, Friesen CK, Schjeldahl K: **What's "up" with God? vertical space as a representation of the divine**. *J Pers Soc Psychol* 2007, **93**:699-710.

74. Cian L, Krishna A, Schwarz N: **Positioning rationality and emotion: rationality is up and emotion is down**. *J Consum Res* 2015 http://dx.doi.org/10.1093/jcr/ucv046.

75. Glenberg AM, Kaschak MP: **Grounding language in action**. *Psychon Bull Rev* 2002, **9**:558-565.

76. Casasanto D, Dijkstra K: **Motor action and emotional memory**. *Cognition* 2010, **115**:179-185.

77. Caruso EM, Van Boven L, Chin M, Ward A: **The temporal doppler effect: when the future feels closer than the past**. *Psychol Sci* 2013 http://dx.doi.org/10.1177/0956797612458804.

78. Hung IW, Labroo AA: **From firm muscles to firm willpower: understanding the role of embodied cognition in self-regulation**. *J Consum Res* 2011, **37**:1046-1064.