How Senses Shape Language:
The Cultural Success of Sensory Metaphors

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Abstract

Why do some linguistic phrases catch on and become more popular than others? There are multiple ways to convey the same thing and linguistic variants with similar meanings often act as substitutes, competing for usage. A not so friendly person, for example, can be described as unfriendly or cold. We study how the senses shape language evolution, suggesting that compared to their semantic equivalents (e.g., unfriendly person), linguistic variants which relate to senses in metaphoric ways (e.g., cold person) should be more culturally successful. Data from 5 Million books over 200 years support this prediction: Sensory metaphors are used more frequently over time than their semantic equivalents. Experimental evidence demonstrates that sensory metaphors are more memorable because they relate more to the senses and have more associative cues. These findings shed light on how senses shape language and the psychological foundations of culture more broadly.
Language varies over time (Christiansen & Kirby, 2003; Evans & Levinson, 2009; Lieberman, Michel, Jackson, Tang, & Nowak, 2007; Schaller, Conway, & Tanchuk, 2002). Some proverbs become more popular than others, some phrases catch on, and some sayings become widely adopted. There are multiple ways to convey the same thing and linguistic variants with similar meanings often act as substitutes, competing for usage. In 1800s, for example, people used the phrase “sudden increase” to refer to a quick rise in something. But the phrase “sharp increase” was introduced around 1900 and is now much more en vogue (Figure 1, based on Google Books corpus, Michel et al., 2011). Similarly, while “promising future” and “bright future” received similar usage in the 1800s, bright future is used 2.4 times as frequently today. Why do certain linguistic variants become more successful than others?

Most factors proposed to affect population-level language change such as status, population size, or levels of outside contact are interpersonal or sociological in nature (Labov, 2001; Nettle, 1999). But language is also one of the most cognitively taxing activities (Boroditsky, 2011; Gibbs & Tendahl, 2006). This implies that cognitive factors that shape linguistic processing may also help determine linguistic success.

Building on research regarding the role of the brain in language evolution (Christiansen & Chater 2008; Chater, Reali, & Christiansen, 2009), and the psychological foundations of culture more broadly (Heath, Bell, & Sternberg, 2001; Kashima, 2008; Schaller & Crandall, 2004), we study how senses shape language. In particular, we propose that linguistic variants that relate to the senses in metaphoric ways should be more culturally successful.
By linking to direct bodily experiences with the physical world, sensory metaphors help express abstract concepts (Clark, 1996; Lakoff & Johnson, 1980). For example, calling an unfriendly person “cold” suggests that, like a blizzard, he is not very inviting. Calling an unpleasant note “sour” suggests that, like a tart taste, it makes you wince.

Sensory metaphorical mappings are not just linguistic quirks, but have wide-ranging consequences for thought, judgment, and decision-making (Landau, Keefer, & Meier, 2011; Lee & Schwarz, 2010; Zhong & Liljenquist, 2006). Starting in childhood, people begin to scaffold abstract concepts onto existing knowledge acquired through sensory experiences (Williams, Huang, & Bargh, 2009). When an abstract concept is encountered (e.g., feeling socially excluded), related sensory concepts (e.g., feeling cold) may be activated (Williams & Bargh, 2008). These activated concepts can then shape downstream behaviors (e.g., tendency to take warm baths, Bargh & Shalev, 2012) or how the situation is described (e.g., a chilly reception, Zhong & Leonardelli, 2008). Thus, abstract concepts can evoke metaphorically relevant sensory experiences, even without the presence of any actual physical sensation.

We suggest that compared to their semantic analogues, sensory metaphors should be more memorable. Multiple streams of research support this notion. First, processing sensory metaphors (e.g., life is a bumpy road) activates the same brain regions as processing sensory experience itself (e.g., feeling roughness, Lacey, Stilla, & Sathian, 2012). Retrieval of sensory knowledge (e.g., cat has fur) is also more automatic and involves less processing than non-sensory knowledge (e.g., cat needs training, Goldberg,
Perfetti, Fiez, & Schneider, 2007). These findings suggest that compared to semantic analogues, sensory metaphors should be easier to retrieve because they are more strongly associated with the senses. Second, while semantic phrases are only stored with their semantic meaning, sensory metaphors are stored in both a semantic (e.g. cold as in unfriendly) and sensory code (e.g. cold as in temperature). This, combined with the frequency of exposure to sensory information in the environment should lead sensory metaphors to be cued more frequently, and thus be more accessible overall.

Greater memorability, in turn, should lead sensory metaphors to be more culturally successful. More memorable concepts are more likely to be used, which increases the chance that other people learn them and then use them in the future (Bandura, 1977). Thus, a reciprocal interaction between the individual and the collective may occur (Gureckis & Goldstone, 2009), whereby initial psychological advantages in memory get magnified through social interaction (also see Chater & Christiansen, 2010).

**Overview of the Present Studies**

Five studies test whether sensory metaphors are more memorable and culturally successful over time. Study 1 examines the usage of sensory metaphors over time. Study 2 shows that sensory metaphors are more memorable than matched semantic analogues, and that this is driven by their sensory nature and increased associative cues. Study 3 provides evidence that the cultural success of sensory metaphors is driven by increased memorability. Study 3 and 4 demonstrate that the success of sensory metaphors is driven
by their sensory, rather than metaphorical nature. Finally, Study 5 underscores the results of the prior studies using a broader set of stimuli.

**Study 1: Usage in 5 Million Books**

Study 1 investigates the cultural success of sensory metaphors. We used Google Books corpus (Michel et al., 2011) to track the number of times sensory metaphors (e.g., cold person) and their semantic analogues (e.g., unfriendly or distant person) were used in over 5 million books from 1800 to 2000. The corpus contains approximately 4% of all books ever printed since 1800 and includes over 361 billion English words.

We used a rigorous procedure to generate a list of sensory metaphors and matched semantic analogues. To control for word frequency, we used only two word (adjective + noun) phrases. All phrases also needed to be reasonably familiar and matched for meaning (e.g., cold person and unfriendly person). First, two coders were given a list of hundreds of sensory adjectives (e.g. bright and cold) retrieved from exhaustive online resources (Cook, 2012; Rosales-Uribe, 2012) and asked to indicate whether the adjectives were familiar or not ($\alpha = 73.1$). For adjectives rated as familiar by both coders, three additional coders used dictionaries and thesauruses to generate sets of one sensory metaphorical phrase (e.g., bright student) and three matched control phrases close in meaning (e.g., intelligent student, smart student and clever student). We included three matched analogues since sensory metaphors can have multiple meanings. To drop phrases that did not make sense (e.g., oily matter) or are never used, three additional coders then rated the familiarity of each sensory metaphor and matched semantic
anallogues (1 = not at all familiar, 7 = extremely familiar). Phrases with above average familiarity ratings (> 4.72) were given to a final set of two coders. Coders reached agreement on thirty-two sets of phrases, each of which included one sensory metaphor and three matched semantic analogues (see Table S1 for the list of phrases).

Data Analysis

Since phrase usage is a count variable aggregated yearly, we used a Poisson model to compare the usage of each sensory metaphor and its semantic analogues over time. We model \( n_{ijt} \), the usage of phrase \( i \) at time \( t \), as a Poisson variable, where \( j \) is “0” for sensory metaphors and “1” for semantic analogues. Consistent with literature on Generalized Linear Models, we model the natural logarithm of the Poisson rate as a function of explanatory variables.

The goal is to estimate what drives the time-varying phrase usage, \( \lambda_{ijt} \). The full description of the model is as follows:

\[
\begin{align*}
    n_{ijt} &= \text{usage of } i^{\text{th}} \text{ sensory metaphor at time } (t), \ j = 0 \\
    n_{ijt} &= \text{usage of } j^{\text{th}} \text{ semantic analogue to the } i^{\text{th}} \text{ semantic analogue at time } t \\
    j &= 0, 1, \ldots, s_i \\
    s_i &= \text{the number of semantic analogues that matches sensory metaphor } i \\
    t &= 1, \ldots, t_i \\
    n_{ijt} &\sim \text{Poisson}(\lambda_{ijt}) \\
    \log(\lambda_{ijt}) &= \mu + \alpha_i + \delta_j + \lambda Z_i \quad \text{[Controls]} \\
    &\quad + (\beta_{11} + \beta_{21} X_j)t \quad \text{[Main parameters of interest]} \\
    \end{align*}
\]

,where \( X_j = 1 \) for \( j = 0 \), \( X_j = 0 \) for \( j > 0 \) \\
\( \delta_j = 0 \) for \( j = 0 \), \( \delta_j = 1 \) for \( j = 1 \) (first semantic analogue), \( \delta_j = 2 \) for \( j = 2 \) (second semantic analogue), \( \delta_j = 3 \) for \( j = 3 \) (third semantic analogue)
In this model we rely on two sets of variables. The first set consists of three “control” effects. First, we controlled for the effect of different nouns ($\alpha_i$). This accounts for the fact that some sets of phrases may be inherently more popular than others because of the nouns they use. For example, there may be just more situations where someone needs to refer to a student being good (and could use phrases like bright, intelligent, or clever student) than the future being good (and could use phrases like bright, promising, or positive future). Given other sets of nouns could have been chosen, nouns used in phrases are treated as a random effect. Second, we controlled for the effect of different adjectives used for semantic analogues $\delta_j$. This accounts for the fact that certain semantic analogues may be more popular than others, which convey similar meanings. Third, we took into account the initial level of sensory metaphors and semantic analogues usage $\lambda Z_i$. This accounts for the fact that initial level usage of sensory metaphors might be higher than semantic analogues.

The second set contains our primary variables of interest: the usage of the sensory metaphors and semantic analogues over time ($\beta_{1l} + \beta_{2l}X_j)$. The coefficient ($\beta_{2l}$) of interaction between time and phrase type indicates how the usage of sensory metaphors changes relative to semantic analogues.

**Results and Discussion**

Figure 2 illustrates the usage of both types of phrases (also see Table S2). As predicted, compared to semantic analogues, sensory metaphors became more successful over time, $\beta_{\text{Time} \times \text{Sensory Metaphors}} = .018, p < .001$. Sensory metaphors and matched semantic
analagues started out as equally popular. But while the usage of semantic analogues increases over time, $\beta_{Time} = .007, p = .001$, the use of sensory metaphors increases even more sharply, $\beta_{Time} = .025, p < .001$. Results are the same allowing for quadratic effects of time (Supplementary Materials).

Ancillary analyses cast doubt on alternative explanations and underscore the robustness of these effects. One could argue that these results are driven by the visual system. It is easier to form a mental picture of visual stimuli and visual imageability can enhance memory (Childers & Houston, 1984; Paivio, 1979). Consequently, compared to metaphors using other senses, it may be easier to form mental images of visual sensory metaphors (e.g., dark moments or bright student) which could make them easier to retrieve and thus more culturally successful.

Our effects, however, hold across sensory modalities (e.g., sound, touch, and taste). Compared to their semantic analogues, even non-visual sensory metaphors are more successful over time, $\beta_{Time* Non-visual Metaphors} = .006, p < .001$. This suggests that the process driving the success of sensory metaphors is broader than the visual system alone.

The results are also not driven by less successful semantic analogues hurting the average. Comparing each sensory metaphor to its most successful analogue shows that sensory metaphors are still more successful over time, $\beta_{Time* Sensory Metaphors} = .017, p < .001$ (Table S3).
Study 2: The Memorability of Sensory Metaphors

Study 2 explores why sensory metaphors became more successful. We examined whether sensory metaphors are more memorable, and whether this is driven by their sensory nature and increased number of associative cues.

One-hundred and fifty-six students received 32 randomly selected phrases (eight sensory metaphors, each with 3 matched semantic analogues) from the list of 128 phrases used in Study 1. They rated each phrase on either how much it relates to the senses (1 = not at all, 7 = strongly) or how many associations it has with other words and ideas (1 = associated with very few things, 7 = associated with many things).\(^1\) After some unrelated filler tasks, participants completed an unaided-recall task where they wrote down as many phrases as they could remember.

Results and Discussion

As predicted, sensory metaphors were more likely to be recalled than their semantic analogues, \(M_{\text{Sensory}} = 28\%; M_{\text{Semantic}} = 18\%; F(1,126) = 25.85, p < .001.\)

Further, sensory metaphors were rated as more related to the senses, \(M_{\text{Sensory}} = 4.64; M_{\text{Semantic}} = 3.00; F(1,126) = 71.65, p < .001\) and as having more associative cues, \(M_{\text{Sensory}} = 4.65; M_{\text{Semantic}} = 4.31; F(1,126) = 8.77, p = .004.\)

To test whether sensory nature and associative cues simultaneously mediate the relationship between phrase type (sensory metaphors vs. semantic analogues) and

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\(^1\) A 2 (dimension rated) x 2 (phrase type) ANOVA on memory confirmed that there was neither a main effect \((F < .60, p > .45)\) nor interaction \((F > 1.3, p = .25)\) of dimension rated on memory.
memory, we conducted a bias-corrected bootstrapping analysis recommended by Preacher and Hayes (2008).

Supporting our theoretical perspective, sensory nature (95% CIs: .001 to .06) and associative cues (95% CIs: .001 to .03) simultaneously mediate the increased memorability of sensory metaphors (Figure 3).

Ancillary analyses also cast doubt on alternative explanations. One might wonder whether sensory metaphors were more memorable because they were more interesting, descriptive, concrete or evoked a greater emotional response. This was not the case. In another study, we asked participants to rate a set of phrases on either interestingness, descriptiveness, concreteness, or the extent to which they evoke an emotional response. Compared to semantic analogues, the sensory metaphors used here did not differ on any of these dimensions ($F$s < .60, $p$s > .25). Thus while these other factors may contribute to cultural success in general, they have difficulty explaining the impact of sensory metaphors on memory observed here.

Finally, as in Study 2, ancillary analyses demonstrate that the higher recall rates for sensory metaphors hold both for visual sensory metaphors, $M_{\text{Visual Sensory}} = 30\%$; $M_{\text{Semantic}} = 19\%$; $F(1, 78) = 13.78$, $p < .001$, and non-visual sensory metaphors $M_{\text{Non-visual Sensory}} = 24\%$; $M_{\text{Semantic}} = 16\%$; $F(1, 46) = 6.79$, $p < .05$. This provides further evidence that the effects observed here are not driven solely by the visual system.
Study 3: Memorability and Cultural Success

Study 3 examines whether more memorable sensory metaphors are more culturally successful. We also tested whether greater sensory nature and increased associative cues are related to cultural success.

We collected a larger set of sensory metaphors by relaxing the constraint that they needed to have matched semantic analogues. Taking the sensory adjectives that were rated high on familiarity in Study 1, two coders used dictionaries and thesauruses to generate sensory metaphors. They reached agreement on 76 sensory metaphors.

Then, using the procedure from Study 2, we had participants (n = 119) rate the phrases on their sensory nature or number of associative links. A delayed recall task measured phrase memorability.

We also tested how sensory nature and prevalence of associative cues related to cultural success. We acquired phrase usage counts in each year from 1800 to 2000 from the Google Books corpus, and applied the following Poisson model:

\[ n_{it} = \text{usage of } i^{th} \text{ sensory metaphor at time } (t), \ t=1 \ldots t_i \]

\[ n_{it} \sim \text{Poisson}(\lambda_{it}) \]

\[ \log(\lambda_{it}) = \mu + (\beta_{1i} + \beta_{2i} * X_i + \beta_{3i} * W_i) t \]  

[Main parameters of interest]

Our main variables of interest are the effect of sensory nature (X_i) and associative cues (W_i) on phrase usage over time.

Results and Discussion

Consistent with Study 2, sensory metaphors that were more sensory in nature, \( \beta_{\text{Sensory}} = .33, \ SE = .01, t (75) = 3.22, p < .005, \) and had more associative cues, \( \beta_{\text{Associative}} = \)
.30, SE = .01, t (75) = 2.96, p < .005, were more likely to be remembered. This indicates that the same processes that led sensory metaphors to be more memorable than their semantic analogues may also influence why sensory metaphors are remembered more.

These factors are also related to cultural success. Consistent Study 1, the usage of sensory metaphors increased over time, $\beta_{Time} = .026, p < .001$. More importantly, metaphors that has better recall (at the individual level) had sharper increases in usage (at the collective level), $\beta_{Time*Memory} = .002, p < .001$. Further, the rate of increase was higher for sensory metaphors that are more sensory in nature, $\beta_{Time*Sensory Nature} = .001, p = .058$ and have more associative cues, $\beta_{Time*Associative Cues} = .003, p < .001$ (Figure 4 and Table S4).

It is difficult (if not impossible) to directly measure phrases’ memorability at different points in the past, but results of Study 3 are at least consistent with the notion that that memory contributes to cultural success. They also provide additional evidence that sensory nature and increased associative cues drive the memorability of sensory metaphors and potentially their cultural success.

**Study 4: Sensory Nature or Metaphorical Nature?**

Study 3 provided evidence that the success of sensory metaphors is driven by their sensory, rather than metaphorical nature. Study 4 further tests this idea by comparing the cultural success of sensory and non-sensory metaphors.

We used the sensory metaphors from Study 3 and collected non-sensory metaphors (e.g., healthy market, stubborn stain) from the Master Metaphors List (Lakoff, Espenson,
& Schwartz, 1991). To generate a reasonable number of phrases (N = 49) we allowed them to be up to four words long.

Next, we used the Google Books corpus to measure how frequently each sensory and non-sensory metaphor was used from 1800 to 2000. We tested whether sensory metaphors were used more frequently over time compared to non-sensory metaphors using a similar model used in Study 1.

**Results and Discussion**

Compared to non-sensory metaphors, sensory metaphors became more successful over time, $\beta_{\text{Time*Sensory Metaphors}} = .005$, $p < .001$ (Figure S1 and Table S5). The usage of non-sensory metaphors increased over time, $\beta_{\text{Time}} = .024$, $p < .001$, but the use of sensory metaphors increased even more sharply, $\beta_{\text{Time}} = .029$, $p < .001$.

Ancillary analyses show that these results were not driven by the fact that the sensory metaphors were somehow more familiar. Three independent coders rated the familiarity of each phrase (1 = not at all familiar, 3 = extremely familiar, $\alpha = .67$). We then ran three separate models comparing sensory and non-sensory metaphors at each level of familiarity. The results remain the same: sensory metaphors are more successful over time (Table S5).

Combined with the results of Study 3, Study 4’s findings underscore the notion that it is their sensory nature in particular, rather than their metaphorical nature, that contributes to sensory metaphors’ cultural success.

One might wonder whether sensory phrases in general, even those without
metaphorical meaning, might also have increased success. While sensory phrases with primary meaning (e.g., warm weather) do relate to the senses, they compete only against other sensory phrases (e.g., hot weather) for use. Consequently, their usage is less likely to depend on their sensory nature per se (which should be similar across competitors) and more by the prevalence of situations in which they could potentially be used (i.e., the actual temperature).

**Study 5: A Broader Set of Sensory Metaphors**

Study 5 tests the generalizability of our effects by using an alternate method to generate a broader set of stimuli.

It may be difficult for people to generate sensory metaphors that are no longer popular, so we used a rigorous procedure to generate a comprehensive list of sensory metaphors that could have existed at any point in time. First, exhaustive online resources (Cook, 2012; Rosales-Uribe, 2012) were used to generate the list of sensory adjectives (N = 366). To form a list of nouns (N = 1575), we used the word list Oxford 3000 (2007) which is a list of words selected by language experts for their importance and usefulness in the English language. We then combined these two lists to form all possible combinations (N = 576,450).

Second, we retrieved the usage counts for each combination from Google Books corpus. Not surprisingly, many of the combinations did not make sense, or were never used with any frequency, so we filtered out any phrases that were used less than 5000 times in the last 200 years. Third, to ensure that the combinations were actually sensory
metaphors (rather than sensory phrases with primary meanings e.g., cold water) we took
the remaining 5432 phrases, gave independent coders a definition of sensory metaphors,
and had them rate each phrase on whether or not it was a sensory metaphor (1 =
definitely not a sensory metaphor, 3 = definitely a sensory metaphor). Phrases rated as
definitely sensory metaphors (N = 377) were retained for further analysis.

Similar to Study 3, we then examined whether phrases that had higher sensory
nature and more associative cues were used more frequently over time. Two sets of four
coders each used 7-point scales to rate the final set of sensory metaphors on either how
much they relate to senses or how many associations they have with other words and
ideas (α’s = .63 and .69 respectively). We retrieved phrase usage counts each year from
1800 to 2000 from the Books corpus, and applied the same model used in Study 3.

Results and Discussion

Consistent with our other studies, usage of sensory metaphors increased over
time, \( \beta_{\text{Time}} = .013, p < .001 \). Further, the rate of increase was higher for sensory
metaphors that are more sensory in nature, \( \beta_{\text{Time}*Sensory\, Nature} = .001, p < .001 \) and have
more associative cues, \( \beta_{\text{Time}*Associative\, Cues} = 1.782E-5, p < .05 \) (Figure S2 and Table S6).

The fact that these effects persist using a vastly different method of phrase
generation suggests that they are not restricted to the particular set of phrases used.
General Discussion

Taken together, these findings identify a potential mechanism through which the senses shape linguistic success. Sensory metaphors became more culturally successful than their semantic analogues and are more memorable because of their higher sensory nature and associative cues. Given the innate, pancultural nature of sensory experience (Landau, Keefer, & Meier, 2011; Shepard, 1984), the success of sensory metaphors should also hold in other language families (e.g., Afro-Asiatic, Sino-Tibetan).

Using sensory metaphors in speech may also facilitate interpersonal interaction. Given the basic nature of sensory experience, sensory metaphors should provide common ground (Clark, 1996) between interaction partners. Consequently, referring to this bedrock level of universally shared human experience may strengthen social bonds, enhance conversation flow, and foster idea exchange.

This research extends recent work on embodied cognition from typically short-term laboratory effects to longer-term cultural-linguistic patterns. Through metaphorical scaffolding, incidental sensory experiences (e.g. touching hard objects) can shape seemingly unrelated judgments (e.g. seeing an interaction partner as rigid, Ackerman, Nocera, & Bargh, 2010). We extend this work to show that similar scaffolding processes impact the cultural success of sensory metaphors, and their memorability. Further research might examine whether priming foundational physical concepts (e.g., distance and temperature) makes the corresponding sensory metaphors easier to encode and retrieve and, as a consequence, used more frequently.

These findings also bolster recent theorizing on the psychological foundations of
culture (Kashima, 2008; Schaller & Crandall, 2004) and the role of the brain in shaping language evolution (Chater & Christiansen 2010; Chater, Reali, & Christiansen, 2009). Some have argued that culture is comprised of many individual units, or memes, that are similar to their genetic equivalents, undergo variation, selection, and retention (Dawkins, 1976). When shared across individuals, psychological processes can act as selection mechanisms, shaping the language, norms, and institutions that make up culture (Heath, Bell, & Sternberg, 2001; Markus & Kitayama, 1991). In this case, the metaphorical link between language and sensory experience may help shape cultural success.
References


Kashima, Y. (2008). A social psychology of cultural dynamics: Examining how cultures are formed, maintained, and transformed. *Social and Personality Psychology Compass, 2*(1), 107-120.


Figure 1. Example Usages over Time
**Figure 2.** Sensory Metaphors are More Successful than Their Semantic Analogues (Study 1)
Figure 3. Sensory Nature and Associative Cues Make Sensory Metaphors More Memorable (Study 2)

Path coefficients represent standardized regression coefficients. The coefficient above the path from sensory metaphors to memory represents the total effect with no mediator in the model; the coefficient below this path represents the direct effect when the mediators were included in the model. Coefficients significantly different from zero are indicated by asterisks (p**<.05, p*<.06). Sensory metaphors are coded as 1 and semantic analogues as 0.
Figure 4. Sensory Metaphors with (A) Higher Sensory Nature and (B) Associative Cues are More Successful (Study 3)
Supplementary Materials

Study 1

A scatterplot of the predicted values by observed values close to a 45-degree line and a pseudo-$R^2$ of 0.89 provide support for the goodness of fit of the model.

Quadratic Model

The quadratic model includes the same set of control effects as described in the linear model. The main parameters of interest are specified by $(\beta_{1l} + \beta_{2l} X_j) t + (\beta_{1q} + \beta_{2q} X_j) t^2$.

Results again show that sensory metaphors are used more frequently over time than their semantic analogues, $\beta_{\text{Time}*\text{Sensory Metaphors}} = .024, p < .001; \beta_{\text{Time}^2*\text{Sensory Metaphors}} = -3.55\text{E}-5, p < .001$. While the usage of sensory metaphors increases with both a positive linear and quadratic trend, $\beta_{\text{Time}} = .014, p = .001; \beta_{\text{Time}^2} = 4.257\text{E}-5, p < .001$, semantic analogues have a negative linear and positive quadratic trend, $\beta_{\text{Time}} = -.010, p < .001; \beta_{\text{Time}^2} = 7.81\text{E}-5, p < .001$ (Table S2).

Understanding the exact interaction pattern in this second model requires combining the linear and quadratic effects, so we take the time derivative of the Poisson model:

$$
\frac{d}{dt} \log(\lambda_{ij}) = (\beta_{1l} + \beta_{2l} X_j) + 2(\beta_{1q} + \beta_{2q} X_j)t
= (\beta_{1l} + \beta_{2l} X_j) + 2(\beta_{1q} + \beta_{2q} X_j)t \quad \text{when} \ X_j = 1 \text{[sensory metaphors]}
= \beta_{1l} + 2\beta_{1q}t \quad \text{when} \ X_j = 0 \text{[semantic analogues]}
$$

The difference in usage over time between sensory metaphors and semantic analogues is $\Delta = (\beta_{1l} + \beta_{2l} + 2\beta_{1q} t + 2\beta_{2q} t) - (\beta_{1l} + 2\beta_{1q} t)$, and can be formulated as $\Delta = \beta_{2l} + 2\beta_{2q} t$. Inserting the coefficient values shows that $\Delta = \beta_{2l} + 2\beta_{2q} t = .024 - 2*3.55\text{E}-5 t$, where $\Delta$ is greater than zero for all values of $t$ (1 $\rightarrow$ 201 years). This indicates that sensory metaphorical phrases become used more frequently than their semantic analogues.
Table S1. Phrases Used in Study 1 and 2

<table>
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<tr>
<th>Set</th>
<th>Sensory Metaphor</th>
<th>1st Semantic Analog</th>
<th>2nd Semantic Analog</th>
<th>3rd Semantic Analog</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loud color</td>
<td>Flamboyant color</td>
<td>Flashy color</td>
<td>Showy color</td>
</tr>
<tr>
<td>2</td>
<td>Cold person</td>
<td>Distant person</td>
<td>Unfriendly person</td>
<td>Unpleasant person</td>
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<td>Dark side</td>
<td>Evil side</td>
<td>Immoral side</td>
<td>Sinful side</td>
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<td>Gloomy moments</td>
<td>Sad moments</td>
<td>Unhappy moments</td>
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<td>Dirty joke</td>
<td>Crude joke</td>
<td>Obscene joke</td>
<td>Vulgar joke</td>
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<td>Cross look</td>
<td>Disapproving look</td>
<td>Hostile look</td>
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<td>Challenging test</td>
<td>Demanding test</td>
<td>Difficult test</td>
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<td>Challenging work</td>
<td>Demanding work</td>
<td>Difficult work</td>
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<td>Popular spot</td>
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<td>Approximate estimate</td>
<td>Ballpark estimate</td>
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<td>Quick increase</td>
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<td>Friendly smile</td>
<td>Kind smile</td>
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<td>Kind welcome</td>
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</tr>
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<td>Solid argument</td>
<td>Convincing argument</td>
<td>Reliable argument</td>
<td>Sound argument</td>
</tr>
<tr>
<td>16</td>
<td>Bitter person</td>
<td>Annoyed person</td>
<td>Displeased person</td>
<td>Resentful person</td>
</tr>
<tr>
<td>17</td>
<td>Sweet nature</td>
<td>Friendly nature</td>
<td>Good nature</td>
<td>Pleasant nature</td>
</tr>
<tr>
<td>18</td>
<td>Bitter lesson</td>
<td>Harsh lesson</td>
<td>Painful lesson</td>
<td>Unpleasant lesson</td>
</tr>
<tr>
<td>19</td>
<td>Bright future</td>
<td>Optimist future</td>
<td>Positive future</td>
<td>Promising future</td>
</tr>
<tr>
<td>20</td>
<td>Bright smile</td>
<td>Cheerful smile</td>
<td>Happy smile</td>
<td>Sunny smile</td>
</tr>
<tr>
<td>21</td>
<td>Bright student</td>
<td>Clever student</td>
<td>Intelligent student</td>
<td>Smart student</td>
</tr>
<tr>
<td>22</td>
<td>Clear evidence</td>
<td>Apparent evidence</td>
<td>Obvious evidence</td>
<td>Sure evidence</td>
</tr>
<tr>
<td>23</td>
<td>Clear language</td>
<td>Coherent language</td>
<td>Comprehensive language</td>
<td>Understandable language</td>
</tr>
<tr>
<td>24</td>
<td>Colorful person</td>
<td>Eclectic personality</td>
<td>Exciting personality</td>
<td>Lively personality</td>
</tr>
<tr>
<td>25</td>
<td>Flat tone</td>
<td>Boring tone</td>
<td>Dreary tone</td>
<td>Lifeless tone</td>
</tr>
<tr>
<td>26</td>
<td>Short reply</td>
<td>Curt reply</td>
<td>Rude reply</td>
<td>Uncivil reply</td>
</tr>
<tr>
<td>27</td>
<td>Small changes</td>
<td>Insignificant changes</td>
<td>Minor changes</td>
<td>Slight changes</td>
</tr>
<tr>
<td>28</td>
<td>Strong argument</td>
<td>Compelling argument</td>
<td>Convincing argument</td>
<td>Persuasive argument</td>
</tr>
<tr>
<td>29</td>
<td>Strong supporter</td>
<td>Fervent supporter</td>
<td>Loyal supporter</td>
<td>Passionate supporter</td>
</tr>
<tr>
<td>30</td>
<td>Sharp mind</td>
<td>Clever mind</td>
<td>Intelligent mind</td>
<td>Quick mind</td>
</tr>
<tr>
<td>31</td>
<td>Straight face</td>
<td>Emotionless face</td>
<td>Poker face</td>
<td>Serious face</td>
</tr>
<tr>
<td>32</td>
<td>Big problem</td>
<td>Considerable problem</td>
<td>Prominent problem</td>
<td>Substantive problem</td>
</tr>
</tbody>
</table>
Table S2. Sensory Metaphors Become Relatively More Successful Over Time (Study 1)

<table>
<thead>
<tr>
<th>Model Term</th>
<th>Linear Model(1)</th>
<th>Linear and Quadratic Model(2)</th>
<th>Exponential Coefficient (Exp $\beta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-3.935</td>
<td>-3.265</td>
<td>0.038</td>
</tr>
<tr>
<td>Time</td>
<td>.007*</td>
<td>-.010*</td>
<td>.990</td>
</tr>
<tr>
<td>Time*Sensory Metaphors</td>
<td>.018*</td>
<td>.024*</td>
<td>1.024</td>
</tr>
<tr>
<td>Time$^2$</td>
<td>7.81E-5*</td>
<td></td>
<td>1.000078</td>
</tr>
<tr>
<td>Time$^2$*Sensory Metaphors</td>
<td>-3.55E-5*</td>
<td></td>
<td>1.000036</td>
</tr>
<tr>
<td>Sensory Metaphors vs. Semantic Analogues</td>
<td>2.110</td>
<td>2.110</td>
<td>8.251</td>
</tr>
<tr>
<td>First Semantic Analogue</td>
<td>-.235</td>
<td>-.254</td>
<td>.776</td>
</tr>
<tr>
<td>Second Semantic Analogue</td>
<td>-.664</td>
<td>-.683</td>
<td>.505</td>
</tr>
<tr>
<td>Third Semantic Analogue</td>
<td>-.059</td>
<td>-.078</td>
<td>.925</td>
</tr>
</tbody>
</table>

*Significant at .05% level. Values in parentheses stand for p values.
Main parameters of interest are indicated in bold. Other parameters are control variables.
Sensory metaphors are coded as 1, and semantic analogues are coded as 0.
The Poisson regression expresses the log of usage as a linear function of the predictors. $\beta$ can be interpreted as increase/decrease in the log of the usage, and Exp $\beta$ as unit increase/decrease in the usage.
**Table S3.** Sensory Metaphors are Used More Frequently than Successful Semantic Analogues over Time (Study 1)

<table>
<thead>
<tr>
<th>Model Term</th>
<th>Coefficient(β)</th>
<th>Exponential Coefficient (Exp β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.369 (0.612)</td>
<td>10.689</td>
</tr>
<tr>
<td>Time</td>
<td>.009* (.000)</td>
<td>1.009</td>
</tr>
<tr>
<td>Time* Sensory Metaphors</td>
<td>.017* (.000)</td>
<td>1.017</td>
</tr>
<tr>
<td>Sensory Metaphors vs.</td>
<td>-2.11 (0.818)</td>
<td>.120</td>
</tr>
<tr>
<td>Successful Semantic Analogue</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05% level. Values in parentheses stand for p values.
Main parameters of interest are indicated in bold. Other parameters are control variables.
Sensory metaphors are coded as 1, and successful semantic analogues are coded as 0.
The Poisson regression expresses the log of usage as a linear function of the predictors. β can be interpreted as increase/decrease in the log of the usage, and Exp β as unit increase/decrease in the usage.
**Table S4.** Sensory Metaphors with Higher Sensory Nature and Associative Cues are Used More Frequently over Time (Study 3)

<table>
<thead>
<tr>
<th>Model Term</th>
<th>Coefficient (β)</th>
<th>Exponential Coefficient (Exp β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.579</td>
<td>4.850</td>
</tr>
<tr>
<td>Time</td>
<td>.026*</td>
<td>1.026</td>
</tr>
<tr>
<td>Sensory Nature</td>
<td>-.452*</td>
<td>.636</td>
</tr>
<tr>
<td>Associative Cues</td>
<td>-.524*</td>
<td>.592</td>
</tr>
<tr>
<td>Time * Sensory Nature</td>
<td>.001*</td>
<td>1.001</td>
</tr>
<tr>
<td>Time * Associative Cues</td>
<td>.003*</td>
<td>1.003</td>
</tr>
</tbody>
</table>

*Significant at .05% level. Values in parentheses stand for p values. Main parameters of interest are in bold. Other parameters are control variables. The Poisson regression expresses the log of usage as a linear function of the predictors. β can be interpreted as increase/decrease in the log of the usage, and Exp β as unit increase/decrease in the usage.
Table S5. Sensory Metaphors are Used More Frequently than Non-Sensory Metaphors over Time (Study 4)

<table>
<thead>
<tr>
<th>Model Term</th>
<th>Full Model</th>
<th>Familiarity=1</th>
<th>Familiarity=2</th>
<th>Familiarity=3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.235</td>
<td>-.123</td>
<td>1.285</td>
<td>1.365</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td>(.519)</td>
<td>(.000)</td>
<td>(.000)</td>
</tr>
<tr>
<td>Time</td>
<td>.024*</td>
<td>.022*</td>
<td>.018*</td>
<td>.027*</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td>(.000)</td>
<td>(.000)</td>
<td>(.000)</td>
</tr>
<tr>
<td>Time*SensoryMetaphors</td>
<td>.005*</td>
<td>.005*</td>
<td>.006*</td>
<td>.002*</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td>(.000)</td>
<td>(.000)</td>
<td>(.000)</td>
</tr>
</tbody>
</table>

*Significant at .05% level. Values in parentheses stand for p values.
Main parameters of interest are indicated in bold.
Sensory metaphors are coded as 1, and non-sensory metaphors are coded as 0.
The Poisson regression expresses the log of usage as a linear function of the predictors. $\beta$ can
be interpreted as increase/decrease in the log of the usage.
Table S6. Sensory Metaphors with Higher Sensory Nature and Associative Cues are Used More Frequently over Time (Study 5)

<table>
<thead>
<tr>
<th>Model Term</th>
<th>Coefficient(β)</th>
<th>Exponential Coefficient (Exp β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.143*</td>
<td>8.524</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>.013*</td>
<td>1.013</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td></td>
</tr>
<tr>
<td>Sensory Nature</td>
<td>-.093*</td>
<td>.912</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td></td>
</tr>
<tr>
<td>Associative Cues</td>
<td>.100*</td>
<td>1.106</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td></td>
</tr>
<tr>
<td>Time * Sensory Nature</td>
<td>.001*</td>
<td>1.001</td>
</tr>
<tr>
<td></td>
<td>(.000)</td>
<td></td>
</tr>
<tr>
<td>Time * Associative Cues</td>
<td>1.782E-5 *</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>(.01)</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05% level. Values in parentheses stand for p values.
Main parameters of interest are in bold.
The Poisson regression expresses the log of usage as a linear function of the predictors. 
β can be interpreted as increase/decrease in the log of the usage, and Exp β as unit increase/decrease in the usage.
Figure S1. Sensory Metaphors are More Successful than Non-Sensory Metaphors (Study 4)
Figure S2. Sensory Metaphors with (A) Higher Sensory Nature and (B) Associative Cues are More Successful (Study 5)