Ease-of-Simulation Norms for 452 Adjective Metaphors

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Abstract

Successful language comprehension results in a multimodal simulation of meaning. Hence, the ease of simulation of a given metaphor is likely to be a critical predictor of performance in metaphor processing. Since simulations are unconscious, and may lose information when brought to conscious awareness, the ease of simulation cannot be directly rated (e.g., as ease of understanding or of generating mental imagery). Therefore, we propose an alternative method of measuring ease of simulation indirectly by assessing the end product of successful metaphor processing using multiple rating scales that, together, offer a proxy for ease of simulation: sensibility, usability, and imaginability of metaphors. We normed 452 sentences comprising adjective metaphors (e.g., *Students can be bright*; *Minutes can be lukewarm*) by asking participants to rate the sentences on sensibility, usability, and imaginability scales. We then used principal components analysis to combine these three individual rating scales into a single measure that captured their common variance: ease-of-simulation (EoS). To validate the norms, we examined the extent to which this new EoS measure can explain response times in a metaphor processing task, and found that it better predicted sensibility judgement times than any of the individual ratings, including the ostensibly more relevant sensibility ratings. These findings support the idea that EoS provides a valuable index of processing effort in metaphor comprehension. We hope these norms will benefit research on metaphor processing and the role of simulation in language comprehension.

Keywords: norms, ease of simulation, metaphor processing, language comprehension

Word count: 4897 words

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Successful language comprehension, regardless of being literal or metaphoric, results in multimodal representations of the concepts. Therefore, the effort expended on generating such a representation is likely to be a critical measure of processing effort. In this paper, we will propose a way to measure this effort during metaphor processing and present a set of norms for a collection of adjective metaphors.¹ We will label this measure “ease of simulation”, which is in line with current theories of conceptual representations suggesting that generating multimodal representations relies on the simulation, or re-activation, of sensori, motor, affective, introspective and other bodily experiences (Allport, 1985; Barsalou, 1999; Glenberg & Gallese, 2012; Niedenthal, 2007).

Simulation has been found to be a crucial component of language comprehension, specifically concerning the generation of semantic representations (Barsalou, 1999; Connell & Lynott, 2014b; Louwerse & Jeuniaux, 2008; Zwaan, 2004). Comprehension of sound-related words such as *thunder*, for example, activates the same brain areas involved in auditory perception (Bonner & Grossman, 2012; Boulenger et al., 2008; see also Hauk, Johnsrude, & Pulvermüller, 2004); the strength of sensorimotor activations facilitates word processing, with a processing advantage associated with words that activate stronger sensorimotor activities (Aravena et al., 2010; Buccino et al., 2005; Connell & Lynott, 2014a; Glenberg et al., 2008; Speed & Majid, 2017). Even abstract concepts – which traditionally have been assumed to lack perceptual information – have been shown to be grounded in people’s sensorimotor and affective experiences (Connell, Lynott, & Banks, 2018; Glenberg et al., 2008; Vigliocco et al., 2014).

¹ Norms available to be downloaded here: <https://goo.gl/9WkWLs>

Simulation in Metaphor Processing

Since evidence suggests that simulation is involved when we process concrete and abstract concepts alike, it is thus reasonable to assume that metaphor processing relies on simulation too. Based on this hypothesis, many ingenious studies have been conducted to verify the activation of sensorimotor cortices during metaphor processing. For instance, Santana and Vega (2011) found a metaphor equivalent of the action-sentence compatibility effect (Glenberg & Kaschak, 2002), that is, reading a metaphor which uses a word of vertical action (e.g., *rise to power*) facilitates the physical action in the same direction, but impedes actions in an opposite direction. Some imaging studies (e.g., Lacey, Stilla, & Sathian, 2012; Schmidt-Snoek, Drew, Barile, & Agauas, 2015) also found that processing metaphors with sensory words (e.g., *coarse language*) selectively activates the somatosensory cortex.

However, these imaging findings have not been widely replicated. For example, metaphors using action verbs (e.g., *grasping the idea*) do not activate the same motor and premotor cortices to the same extent as the literal use of these verbs (e.g., *grasping the handle*; Romero Lauro, Mattavelli, Papagno, & Tettamanti, 2013). Not only so, metaphors do not activate the primary cortices any more than their literal counterpart. That is to say, a sensory metaphor like *a bright student* does not activate the primary visual cortex more than *a clever student* (Citron & Goldberg, 2014; Yang & Shu, 2016). Although these studies sometimes found activations in other regions associated with processing sensorimotor stimuli, these regions are also activated in other cognitive and perceptual processing not related to the specific sensorimotor modalities (Casasanto & Gijssels, 2015). In short, the simulation of the sensorimotor activations of the source domain cannot be the simulation required for processing and comprehending metaphors, at least not entirely.

In fact, neither should it be. Studies on embodied metaphor processing, while using cutting-edge technology and advocating for contemporary theories, is effectively a revival of

the standard pragmatic model (Grice, 1975), which suggested that the literal meaning was always activated prior to the metaphoric meaning. Such an idea has long since lost favour, because researchers have found that many metaphoric meanings enjoy the same, if not greater, priority as the literal meaning (i.e., Graded Salience Hypothesis; Giora, 1997). Even when the literal meaning is activated, it should be quickly suppressed by the context for processing to succeed (Glucksberg & Haught, 2006; MacGregor, Bouwsema, & Klepousniotou, 2015; Peleg, Giora, & Fein, 2001). Boulenger, Shtyrov, and Pulvermüller (2012) used MEG, with a higher temporal resolution than fMRI, to find that source domain activation only happened at an early time window (150ms - 250ms), and was suppressed during later time when semantic processing is supposed to occur.

As a result, in our endeavour to study simulation during metaphor processing, it is not necessarily helpful to limit ourselves to the activations in the sensorimotor areas by the source word. In fact, for the purpose of quantifying the effort expended on conceptual representations, the content of the representation (and how it is related to the source domain), we would argue, is beside the point. There is no reason to assume that the extent of activations in a certain sensorimotor modality can stand for the effort it takes to generate a coherent representation of meaning. *A bright student* may activate the visual cortex more than, say, *a bright illness* because the former can more easily generate a visual scene of a clever student participating in group discussions than the latter, but it may also be the opposite case because people, in the latter case, need to try very hard to generate a meaningful representation for the word *bright*. The same argument could be made for any sensory, motor, affective and simulations in other modalities.

Therefore, in order to examine the effort of conceptual representation as a whole, we propose to measure ease of simulation (EoS) indirectly, by measuring the effort to achieve successful conceptual representation in various language processing tasks. Three tasks were used in this norming study to tap into different, but complementary, aspects of successful language comprehension and conceptual representation, namely sensibility,

usability and imaginability judgements. Sensibility, that is, how much sense a sentence makes if encountered in reading or in conversation (e.g., *Students can be bright*), is common measures used in psycholinguistic studies to assess processing difficulties. It is a useful measure that relates to whether the process of language comprehension seems to have produced a functional end product. By successfully “making sense” of a metaphor, people will manage to construct a conceptual representation of the metaphoric meaning in question.

Imaginability, that is, how easy it is to imagine the concept described in a metaphor – is introduced to give a lay definition of simulation. Although imagining a concept requires conscious effort while simulation is unconscious, both processes depend on generating, retaining and even manipulating mental representations. Note that imaginability is not imageability, the latter of which relates to generating sensory imagery and is biased towards concrete concepts and the visual modality (Connell & Lynott, 2014b; Paivio, Yuille, & Madigan, 1968). In contrast, imaginability (i.e., how easy it is to imagine the concept described in a metaphor) can be easily applied to abstract concepts. People could find it as easy to imagine an abstract concept such as *a bright future* as a concrete concept such as *a bright student*.

Usability, furthermore, is a novel measure we propose to encourage participants to engage in deeper processing. By assessing how easy it is to use the sentence in conversation or in text, we hypothesise that people do not only need to understand and make sense of a sentence, but also need to think of scenarios where they might reasonably produce the sentence, which would be very difficult without thorough and confident grasp of what the metaphor actually means. These three tasks were used to produce a composite measurement of the effort for generating conceptual representations, which distinguishes this EoS norms from previous norming studies of metaphor processing.

Comparison with Previous Norms

There already exist several metaphor norms which try to measure a similar construct as the present EoS norms (Campbell & Raney, 2015; Cardillo, Schmidt, Kranjec, & Chatterjee, 2010; Katz, Paivio, Marshark, & Clark, 1988; Roncero & Almeida, 2014). The common method for norming in these studies, as well as the present study, is to rate a body of metaphors on a number of Likert scales. However, these previous norming studies tend to neglect the fact that these scales are correlated. Campbell and Raney (2015), replicating Katz et al. (1988), collected ratings on 10 scales, including comprehensibility, ease of interpretation, metaphoricity, metaphor goodness, metaphor imagery, subject imagery, predicate imagery, familiarity, semantic relatedness and alternative interpretations. Cardillo et al. (2010) collected ratings on 5 scales, which were familiarity, naturalness, imageability, figurativeness and number of interpretations. Similarly, Roncero and Almeida (2014) collected ratings on conventionality, connotativeness, aptness and familiarity. In spite of the fact that scales such as metaphoricity and familiarity should measure distinct constructs, in Campbell and Raney (2015), all scales correlated with one another with $r > .94$, apart from alternative interpretations which still correlated with other scales with $r > .83$. Roncero and Almeida (2014) also found that familiarity correlated with conventionality ($r = .30$) and aptness ($r = .73$) significantly. Similarly, Cardillo et al. (2010)'s norms also found significant correlations between most of the scales (r ranging from .25 to .96).

The high correlation between scales seem to suggest that there are underlying dimensions which explains the variance of these norms. Indeed, Thibodeau, Sikos, and Durgin (2017) found two underlying dimensions that explained 93% of the variance of five common rating scales (i.e., surprisingness, comprehensibility, familiarity, metaphoricity and aptness). The first dimension, dubbed processing fluency (i.e., the ease with which people process a metaphor) correlated highly with comprehensibility, familiarity and aptness; whereas the second dimension, dubbed figurativeness correlated with surprisingness and

metaphoricity and inversely with familiarity. Only the former dimension predicted response times towards the metaphors. A similar result by Littlemore, Sobrino, Houghton, Shi, and Winter (2018) also suggested that sensibility judgement times were influenced by the metaphor’s conventionality/novelty; whereas “metaphor quality”, a composite measure of how much the metaphor made sense, the level of its quality and whether it was generated by a human did not. The broad similarity between Thibodeau et al. (2017) and Littlemore et al. (2018) lies in the result that RT, which is a measure of the difficulty in metaphor processing, can be reliably predicted by a measure of the effort of processing, albeit operationalised by different rating scales.

It is this dimension of processing effort that we intend to measure in this paper. From previous norming studies, we maintain that it is necessary, and hugely beneficial, to produce a composite measure as we do with EoS, which capture the underlying mechanism to generate a coherent conceptual representation while removing superficial variances that related to individual scales. Critically, we designed the EoS measure to make the distinction between simulation and linguistic distributional information in conceptual representation, in accordance with recent theories of the conceptual system that assume both contribute independently to processing meaning and concepts (e.g. Barsalou, Santos, Simmons, & Wilson, 2008; Connell & Lynott, 2014b; Louwerse & Jeuniaux, 2008). Indeed, the linguistic distributional patterns of how words co-occur in language (e.g., co-occurrence frequencies of *students* and *bright*) has been shown to affect conceptual representations and the speed of language processing beyond the contribution of simulation (Connell, 2018; e.g., Connell & Lynott, 2013; Louwerse & Jeuniaux, 2010). However, previous norming studies did not pay attention to disentangling distributional patterns from their measures of the effort of processing. Thus, we will ensure that EoS is not correlated with the linguistic distributional frequency (LDF). As such, the present metaphor norms achieve a level of theoretical and empirical distinctness that other norms do not.

We will provide a body of 452 sensory metaphors in the form of “NOUN can be

ADJECTIVE” (e.g., *Students can be bright*). The composite measure should offer a proxy of how easy it is to simulate a concept in a successful representation of metaphoric meaning. If so, EoS should, first of all, capture the majority of variance of the rating tasks. Second, it should be able to outperform the individual rating scales in predicting the performance of metaphor processing. In Norms Validation, we will conduct such a test by comparing EoS with the rating scales in predicting the RT to a sensibility judgement task (Liu, Connell, & Lynott, 2017).

Norming Procedure

This norming study aimed to operationalise EoS in metaphor processing. For this purpose, we generated metaphoric sentences in the form of “A can be B” in which A was a noun as the target word and B was a sensory adjective as the source word (e.g., *Student can be bright*). We asked participants to rate these sentences on their sensibility, usability and imaginability, and we combined these three sets of ratings using principal components analysis (PCA) to obtain a single score for each item. The full set of metaphors, along with ratings, EoS, and linguistic distributional frequencies, is made public online (<https://goo.gl/9WkWLs>).

Method

Participants. We recruited 171 students from Lancaster University to complete the survey. All were native speakers of English. They took part in the study either online for a chance to win a £10 Amazon voucher ($N = 112$) or in a lab for a reward of £3 ($N = 59$).

Materials. A basic set of 113 object properties (i.e. adjectives), that were unimodal in their literal meanings (i.e., had a single dominant perceptual modality: see also Liu, Connell, & Lynott, 2018), were selected from the modality exclusivity norms of Lynott and Connell (2009). Each adjective was paired with four nouns (chosen from various sources

such as the Kenkyusha Dictionary of English Collocations (Katsumata, 1980), Macmillan English Dictionary (Rundell, 2007), Oxford Dictionary of English (Stevenson, 2010)) in order to generate sentences with different metaphoric interpretations, giving a total of 452 metaphors. When generating the metaphors, we made sure that it was the adjectives, rather than the nouns, that were interpreted metaphorically, and that the metaphors did not have a literal meaning readily accessible (e.g., *Feet can be itchy*, meaning wanting to travel, was rejected as a possible item because both *feet* and *itchy* were interpreted metaphorically and the literal meaning of an itching sensation was readily accessible too).

The combination of each adjective with four nouns enabled the metaphors to vary independently on two dimensions: that is, the researchers' initial intuitions of the ease of simulation and a measure of linguistic distributional frequency (i.e., how often the adjective and noun co-occurred). Linguistic distributional frequency is a simple, off-the-shelf measure of distributional patterns; and has been shown to affect conceptual representations and the speed of language processing (Connell & Lynott, 2013; Louwerse & Jeuniaux, 2010; Louwerse, Hutchinson, & Cai, 2012), because things that often appear together in the world also tend to be mentioned together in language (Kintsch & Dijk, 1978; Louwerse & Jeuniaux, 2010). Therefore, when norming the EoS for the adjective metaphors in this study, we also need to take the linguistic distributional frequency into account to make sure that any measure of EoS is not entirely confounded by linguistic distributional frequency. In order to do so, linguistic distributional frequency and researchers' intuition of EoS were varied independently when creating metaphors for each adjective, so that items could be roughly categorised into 4 groups² (easy-high: *Students can be bright*, hard-high: *Supply can be bright*, easy-low: *Solutions can be bright*, hard-low: *Illness can be bright*).

Researchers' intuition of EoS ranged from easy (e.g., the meaning of the metaphor *Students can be bright* is likely to be represented relatively easily as a quick-witted,

² This categorical distinction was for list generation only. Variables EoS and LDF are both continuous variables in the norms.

Table 1
*Sample metaphors, and their scores for EoS (PC1)
 and LDF*

Metaphor	EoS (PC1)	LDF
<i>Illness can be bright.</i>	-1.32	2.95
<i>Supply can be bright.</i>	-1.02	3.72
<i>Solutions can be bright.</i>	1.41	3.11
<i>Students can be bright.</i>	1.84	4.08
<i>Minutes can be lukewarm.</i>	-1.49	3.31
<i>Scheme can be lukewarm.</i>	-0.78	1.61
<i>Supporters can be lukewarm.</i>	0.69	2.69
<i>Reaction can be lukewarm.</i>	1.03	3.45

intelligent students) to difficult (e.g., the meaning of the metaphor *Supply can be bright* is likely to be represented only with great difficulty, if at all). The metaphors also varied on the dimension of linguistic distributional frequency, which was determined by the bi- to 5-gram co-occurrence frequencies between the adjective and the noun with zero to three intervening words (e.g., “bright students” or “students bright”, “bright . . . students” or “students . . . bright”, etc.) in the Google Web1T Corpus (Brants & Franz, 2006).

Frequencies were log transformed as $\log_{10}(\text{frequency} + 41)$ because 41 is the lowest non-zero frequency in the corpus (i.e., the raw frequency of 0 in fact means that the constituent words co-occurred 41 times; e.g., Connell & Lynott, 2013). Thus, we obtained a linear scale of linguistic distributional frequency for all metaphors normed ($M = 2.95$, $SD = 0.97$). Linguistic distributional frequency ranged from high (e.g., *Student can be bright*) to low (e.g., *Solution can be bright*).

Procedure. In order to operationalise EoS, we asked participants to rate the sentences on three scales – sensibility (i.e., how much sense the expression makes as if read in a story or heard in conversation), usability (i.e., how easy it would be to use the expression in writing or conversation), and imaginability (i.e., how easy it is to imagine the concept described in the expression). In the survey, each metaphoric expression was rated

on these three criteria on a 1-7 Likert scale, with 1 being “making no sense at all”, “very hard to use/imagine” and 7 being “making perfect sense”, “very easy to use/imagine” (full instructions are given in Appendix).

With the four groups of adjective-noun pairs (easy/hard to simulate x high/low linguistic distributional frequency) and three scales of rating, we generated twelve list conditions of items to which each participant was assigned based on their month of birth. Each participant saw 113 items that ranged across a full spectrum from easy to hard to simulate, and from high to low distributional frequency, and were distributed in approximately equal proportions across the three ratings scales. Thus, all items were rated on all three scales, but each participant rated a particular adjective only once. The order of item presentation under each scale was randomised prior to the study and the order of scale presentation was randomised for each participant. Participants were not compelled to rate all items but could complete as many as they wanted to.

The survey was administered both online and in a lab setting with the permission of the Lancaster University’s Department of Psychology Ethics Committee and Lancaster University’s Research Ethics Committee. In both instances, participants completed the entire study via the Qualtrics online survey platform.³ Here, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.⁴

³ We compared ratings in the lab versus online using mixed-effect linear models with the test setting as the fixed effect, and participants and metaphor item as random-intercept effects; overall, online ratings were higher than the ratings in the lab for both imaginability ($b = -0.46$, 95% CI = $-0.79 - -0.12$, $df = 164.09$, $t = -2.65$, $p = .009$) and sensibility ($b = -0.51$, 95% CI = $-0.82 - -0.20$, $df = 160.40$, $t = -3.20$, $p = .002$), but not for usability ($b = -0.25$, 95% CI = $-0.58 - 0.09$, $df = 166.09$, $t = -1.44$, $p = .15$). This comparison should be treated with caution because online participants greatly outnumbered the participants in the lab, with some items rated more than ten times online but only once or twice in the lab.

⁴ We used R (Version 3.5.0; R Core Team, 2018) and the R-packages *bookdown* (Version 0.7; Xie, 2018a), *broom* (Version 0.4.4; Robinson, 2018), *ggplot2* (Version 2.2.1; Wickham & Chang, 2016), *knitr* (Version 1.20; Xie, 2018b), *lme4* (Version 1.1.17; Bates, Maechler, Bolker, & Walker, 2018), *lmerTest* (Version 3.0.1; Kuznetsova, Bruun Brockhoff, & Haubo Bojesen Christensen, 2018), *Matrix* (Version 1.2.14; Bates & Maechler, 2018), *MuMIn* (Version 1.40.4; Bartoń, 2018), *nlme* (Version 3.1.137; Pinheiro, Bates, & R-core, 2018), *papaja* (Version 0.1.0.9735; Aust & Barth, 2018), *psych* (Version 1.8.4; Revelle, 2018), and *rcartocolor* (Version 0.0.22; Nowosad, 2018) for all our analyses and the writing up of this manuscript.

Analysis and Discussion

Data exclusion and treatment. A total of 17,329 data points was collected. Participants who completed less than one-third of the items each scale (i.e., 13 items or fewer) were removed (three participants for imaginability, nine for sensibility, eight for usability). Those who provided the same rating value for more than one-third of the items in a row were removed too (one for imaginability, one for sensibility, four for usability). Two participants' ratings on imaginability were removed because their small number of data points, combined with low variability, meant that calculation of Cronbach's alpha could not proceed (error message: "missing value in the correlation R-package {psych}: Revelle, 2017"). Thus, 16,888 data points remained after exclusion, with a minimum of 10 points per item per scale. The inter-rater consistency was calculated per group (months of birth from January to December) per scale using Cronbach's alpha, and showed that response was highly consistent among participants (imaginability average $\alpha = 0.888$, sensibility average $\alpha = 0.907$, usability average $\alpha = 0.896$). Detailed results of Cronbach's alpha are reported in Supplementary Materials (<https://goo.gl/9WkWLs>).

Extracting the ease-of-simulation (EoS) measure.

We first calculated means and standard deviations of each item per scale, and then we performed PCA via covariance matrix on the three sets of ratings in order to extract one factor. This single factor had an eigenvalue of 2.73, was the only principal component with eigenvalue > 1 , and explained 91% of the total variance of the ratings. The fact that sensibility, usability, and imaginability ratings could be collapsed so successfully into a single component suggested that these three rating scales essentially captured the same underlying information: that is, successful generation of a conceptual representation.

We then used the factor score of this single principal component (estimated via regression as a standardised variable) as the EoS score for each metaphor item. That is, the higher the EoS score, the easier it was to simulate the metaphoric meaning. The factor

Table 2
Correlations among variables with their means and standard deviations (SD)

	1.	2.	3.	4.	5.	<i>M</i>	<i>SD</i>
1. EoS	–	.95	.96	.96	.27	0.00	1.00
2. Imaginability	–	–	.86	.86	.23	3.98	1.44
3. Sensibility	–	–	–	.87	.26	3.83	1.55
4. Usability	–	–	–	–	.28	3.63	1.48
5. LDF	–	–	–	–	–	2.96	0.97

scores are standardised because of PCA, resulting in $M = 1.00$, $SD = 0.00$. Table 2 shows the descriptive statistics of and inter-correlations between the EoS measure, the three rating scales and LDF. It is notable that the three individual ratings scales correlate equally well with each other ($r_s = .86 - .87$) but less well than they do with the extracted ease of simulation measure ($r_s = .95 - .96$), suggesting that each rating scale captures unique variance as well as that related to conceptual representations. We test the utility of this unique variance in the norms validation.

Comparison with LDF.

In creating our metaphors, we attempted to ensure that EoS was not confounded by LDF; that is, the effort of generating a conceptual representation for a metaphoric should not be a function of how frequently the words in that metaphor co-occur in language. In order to examine if we were successful in our efforts, we calculated the relationship between the LDF for each item and the corresponding measures from our norming procedure. As shown in Table 2, LDF had a relatively consistent, positive relationship with EoS scores and their constituent imaginability, sensibility, and usability ratings. However, the relationship was weak, with LDF explaining only 7.3% of the variance in EoS. As such, EoS was not strongly influenced by LDF: the words that comprise an easy-to-simulate metaphor may co-occur seldom or often, as may those that comprise a hard-to-simulate metaphor. Examples of metaphors varying on the EoS measure and LDF are shown in Table 1.

Norms Validation

If ease of simulation is a critical factor in metaphor processing, as assumed by grounded theories for all language processing, then our newly created EoS measure should outperform the three individual scales (imaginability, sensibility, usability) in predicting the time-course of metaphor processing. That is, since each of the three individual rating scales captures only some of the information that exemplifies a successful sensori-motor-affective simulation of metaphoric meaning, their individual ability to predict metaphor processing performance will be less than that of the composite EoS score. We therefore validated our norms by analysing response time (RT) data from a typical metaphor comprehension study: a sensibility judgement task, taken from a previous study by Liu et al. (2017). In that experiment, 28 participants read the 452 metaphors normed here and judged whether or not the sentences made sense. The sentences were presented one word at a time, and RT was measured from the onset of the adjectives to the onset of response.

Liu et al. (2017) found that the EoS scores obtained from the present norming study were a significant predictor of the RT to judge the metaphors as sensible. Here, we directly compare ease of simulation with imaginability, sensibility, and usability ratings in terms of their abilities to predict these sensibility judgement times. We analysed each predictor separately in a mixed-effect linear regression, where the key predictors (EoS, imaginability, sensibility, or usability) were standardised over the entire RT dataset ($M_s = 0$, $SD_s = 1$) and used as fixed effects, and participant and item were crossed random factors modelling random intercept. The imaginability, sensibility and usability ratings were all centred before analysis.

Furthermore, we also investigated whether the composite variable of EoS was a effectual measure for conceptual representation across all three source modalities normed (i.e., vision, audition, and haptics). Two forces could render EoS a more effectual measure for certain modalities than others. On one hand, there is an overall visual dominance in

language (San Roque et al., 2015), which means that visual words are more commonly encountered, and thus may be easier to make sense of, imagine or use. On the other hand, studies on synesthetic metaphors (which occupies 10% of the metaphors normed according to researchers’ intuition) have found that there are more metaphors using words from “lower” sensory modalities (haptics, gustation and olfaction) to describe “higher” sensory modalities (vision and audition; Ullmann, 1959; Williams, 1976) than the reverse; and those metaphors with a lower-to-higher mapping tend to be more easily recalled, interpreted and often judged more natural (Lievers, 2015; Shen & Aisenman, 2008). Thus, it is possible that EoS may be a good predictor only for visual or haptic metaphors, rather than being an equally good predictor for all metaphors. To examine the possibility, we coded the data by the perceptual modality of the adjective source domain (audition, haptics and vision), and analysed whether the EoS effect differed across the source domains.

EoS Measure versus Individual Rating Scales

All four variables (EoS, imaginability, sensibility, usability) had a significant negative relationship with RT in their respective analyses. That is, the easier it is to simulate the meaning of a metaphor (or the more sensible, easy to use, or easy to imagine the metaphor seemed to be), the faster it was accepted as sensible. Table 3 shows the effects of the variables separately in each model.

From the table, it can be seen that the EoS measure had a numerically larger effect size ($b = -149.97$) than the other variables, suggesting it as a better predictor of the response times compared to the other measures. The Bayesian Information Criteria (BIC) also suggested that the model with EoS as a predictor was the best model for RT. To evaluate evidence for the advantage of the EoS measure over others, we calculated the relevant Bayes Factors for the purpose of model comparison. Bayes factor (BF) is a powerful tool to compare models and shows the ratio of the likelihood of data given different hypotheses. It could be used to make a statement about the amount of evidence

Table 3
Results from the mixed-effects linear regressions of RT (ms) in a sensibility judgement task

	<i>b</i>	95% CI	<i>p</i>	AIC
zEoS	-149.97	-178.09 -121.84	< .001	21597.14
zImaginability	-141.65	-169.92 -113.37	< .001	21605.64
zSensibility	-136.75	-165.76 -107.73	< .001	21613.37
zUsability	-141.79	-169.96 -113.61	< .001	21605.47

Note. *b* is unstandardised regression coefficient. However, all predictors were standardised so unstandardised coefficients are directly comparable and represent the ms increase in RT for each SD increase of the predictors.

Variables were fixed predictors in separate models.

for the alternative hypothesis compared against the null hypothesis, in contrast to a simple null-hypothesis significance testing using *p*-values (Jarosz & Wiley, 2014; Wagenmakers, 2007). In the current study, we contrasted the model with the EoS measure (alternative hypothesis H_1) with each of those models with individual ratings (imaginability, sensibility or usability: null hypotheses H_0 s) and calculated the amount the evidence that favoured the EoS model (BF_{10}).

We used the Bayesian Information Criterion (BIC) to estimate the likelihood of data under each hypothesis (Wagenmakers, 2007). We extracted BIC for each model, and then calculated BF_{10} as follows.

$$BF_{01} = e^{\frac{(BIC(H_1) - BIC(H_0))}{2}}$$

In all three comparisons, the Bayes Factors showed very strong evidence in favour of the EoS variable, in comparison with imaginability rating ($BF_{10} = 101.36$), sensibility rating ($BF_{10} = 5174.10$), and usability rating ($BF_{10} = 95.15$). Figure 1 visually illustrates the advantage of EoS over the other measures (for details of model comparison, see Supplementary Materials: <https://goo.gl/9WkWLs>). In other words, ease of simulation

was the best predictor of the speed of accepting metaphors as sensible. This finding suggests that the unique variance in each individual rating scale is noise rather than useful information regarding conceptual representation, and that the shared variance between the scales – as captured by the composite EoS measure – succeeds in capturing useful information about meaning representation that indexes the latency of comprehension.

Figure 1. Effects of EoS measure, imaginability, sensibility and usability on RT (in order of the predicting power). All predictors were standardised so unstandardised coefficients are directly comparable and represent the ms increase in RT for each SD increase of the predictors. The asterisks show the amount of evidence in favour of the EoS model. *: $BF_{10} > 10$; **: $BF_{10} > 100$; ***: $BF_{10} > 1000$.

Examining the Effect of Source Modalities

Although the EoS measure was shown to be the best predictor of RT, it could be argued that its effect is mainly driven by metaphors of certain source sensory modalities

Table 4
*Summary of Hierarchical Model Comparison for Variables to Predict
 Sensibility Judgement RT*

	b	95% CI	R^2	ΔR^2
Model 1			.057	
EoS	-147.89	-176.48 – -119.29		
Perceptual modality				
Haptic - auditory	14.25	-55.20 – 83.71		
Visual - auditory	-37.90	-96.04 – 20.23		
Model 2			.057	< .001
EoS	-151.92	-197.43 – -106.42		
Perceptual modality				
Haptic - auditory	10.77	-72.04 – 93.57		
Visual - auditory	-41.01	-107.70 – 25.69		
EoS x perceptual modality				
EoS x Haptic - auditory	7.04	-70.90 – 84.98		
EoS x Visual - auditory	6.34	-55.13 – 67.81		

Note. b is non-standardised regression coefficient

R^2 stands for marginal R^2 , which represents the variance explained by the fixed factors only.

(i.e., visual metaphors and/or haptic metaphors). We analysed the sensibility judgment times in mixed-effect linear regressions in a step-wise fashion with EoS and the source sensory modality of the adjectives as fixed predictors.

Model 1 included the EoS measure and perceptual modality as fixed variables and participants and items as crossed random-intercept variables, and Model 2 included the critical EoS x perceptual modality interaction as additional fixed variables. The perceptual modality was dummy coded with the visual modality as the reference level. The EoS measure remained a significant predictor of RT (see Table 4). The interactions between source perceptual modality and EoS measure were not significant and the marginal R^2 (Bartoń, 2016) showed that the interaction term could not account for the data better. In other words, EoS did not have different effects on metaphors of different source modalities.

General Discussion

We presented ease of simulation (EoS) norms for 452 metaphors, a novel normed variable that was designed to reflect the ease of successful generating a conceptual representation of metaphoric meaning. We created this EoS measure by collecting imaginability, sensibility and usability ratings on 452 metaphors with 113 unimodal sensory adjectives as the source term (e.g., *Student can be bright*), and generated a composite variable to measure the effort it takes to generate coherent conceptual representations, which we labelled “ease of simulation”, based on current theories of conceptual representation (Barsalou et al., 2008; Zwaan, 2004). The resulting norms were valid as we showed that the three rating subscales could collapse to EoS almost perfectly (93% of variance), and that EoS could outperform each subscale in predicting RTs in a sensibility judgement task. It suggests that EoS can capture more comprehensively the information that exemplifies the simulation of meaning in metaphor processing.

The advantage of EoS over individual subscales was particularly striking when we consider that EoS outperformed the sensibility subscale in predicting performances in a sensibility judgement task. This result particularly echoed our point that it is necessary and beneficial to study conceptual representation using a composite measure such as EoS. Because metaphor ratings involve consciously inspecting the contents of a mental representation, and since it is not possible to inspect the full contents of a representation without losing information (Connell & Lynott, 2016), we suspected that sensibility ratings, and usability and imaginability ratings alike, would capture only some of the necessary criteria that determine how quickly metaphors are processed and judged. By comparing individual subscales with EoS, we could see that each subscale include a good deal of noise that is unrelated to the effort of metaphor processing (e.g., grammaticality judgement, lexical frequency, etc.) as well as useful information that is ultimately captured by EoS.

As we found that EoS is an ideal predictor of processing effort, it can be used to

study various aspect of conceptual representation. Apart from predicting RT (as we show in our validation of the norms), we anticipate that it may also predict other measures of processing effort such as pupil dilation in eyetracking. Moreover, we are currently exploring the utility of EoS as a means of tracking the timecourse of metaphor processing in EEG, and we hope that EoS will prove useful in EEG and MEG paradigms due to its ability to capture - as generally as possible - the effort involved in generating a mental representation of meaning.

As we intentionally distinguished EoS from LDF (i.e., measures of linguistic distributional pattern), EoS can be a good candidate to study linguistic- and simulation-based conceptual representation, and be used to account for the aspects of conceptual processing that are not concerned with linguistic distributional information: that is, the simulation component. It would also allow researchers to separate the activation of deeper (simulation-based) representations of meaning from those of shallower linguistic distributional associations. Future research will be able to take into account other factors that affect conceptual representations such as task demand and depth of processing.

Finally, the norming methodology for EoS is useful in its own right beyond the normed stimuli we present in the current paper. Researchers can create EoS norms for perceptual metaphors in other languages in order to enable cross-linguistic comparisons of metaphor processing. They can also create EoS norms for other non-metaphoric stimuli (i.e., any phrase or sentence) where it would be useful to have a predictor of the effort of generating conceptual representations, particularly when it can be separated from linguistic distributional information.

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Appendix

Instructions of the metaphor norming tasks

Sensibility: You will read a list of sentences about everyday items (e.g. Socks are elastic). Your task is to rate **how much sense the sentence makes as if you had read it in a story or heard it in conversation**, on a scale of 1 – 7 where **1 = no sense at all** and **7 = perfect sense**. Take your time, and please do as many as you can even if you cannot finish them all.

Usability: You will read a list of sentences about everyday items (e.g. Socks are elastic). Your task is to rate **how easy it would be for you to use the sentence in writing or in conversation**, on a scale of 1 – 7 where **1 = impossible to use** and **7 = very easy to use**. Take your time, and please do as many as you can even if you cannot finish them all.

Imaginability: You will read a list of sentences about everyday items (e.g. Socks are elastic). Your task is to rate **how easy it is for you to imagine the concept described in the sentence** (e.g., how easily you can imagine that socks might be elastic), on a scale of 1 – 7 where **1 = impossible to imagine** and **7 = very easy to imagine**. Take your time, and please do as many as you can even if you cannot finish all.