

Visualizing the Obvious: A Concreteness-based Ensemble Model for Noun Property Prediction

Yue Yang*, Artemis Panagopoulou*,
Marianna Apidianaki, Mark Yatskar, Chris Callison-Burch

Department of Computer and Information Science, University of Pennsylvania

{yueyang1, artemisp, marapi, ccb, myatskar}@seas.upenn.edu

Abstract

Neural language models encode rich knowledge about entities and their relationships which can be extracted from their representations using probing. Common properties of nouns (e.g., *red strawberries*, *small ant*) are, however, more challenging to extract compared to other types of knowledge because they are rarely explicitly stated in texts. We hypothesize this to mainly be the case for perceptual properties which are obvious to the participants in the communication. We propose to extract these properties from images and use them in an ensemble model, in order to complement the information that is extracted from language models. We consider perceptual properties to be more concrete than abstract properties (e.g., *interesting*, *flawless*). We propose to use the adjectives' concreteness score as a lever to calibrate the contribution of each source (text vs. images). We evaluate our ensemble model in a ranking task where the actual properties of a noun need to be ranked higher than other non-relevant properties. Our results show that the proposed combination of text and images greatly improves noun property prediction compared to powerful text-based language models.

1 Introduction

Common properties of concepts or entities (e.g., “*These strawberries are red*”) are rarely explicitly stated in texts, contrary to more specific properties which bring new information in the communication (e.g., “*These strawberries are delicious*”). This phenomenon, known as “reporting bias” (Gordon and Van Durme, 2013; Shwartz and Choi, 2020), makes it difficult to learn, or retrieve, perceptual properties from text. However, noun property identification is an important task which may allow AI applications to perform commonsense reasoning in a way that matches people’s psychological or cognitive predispositions, and can improve agent

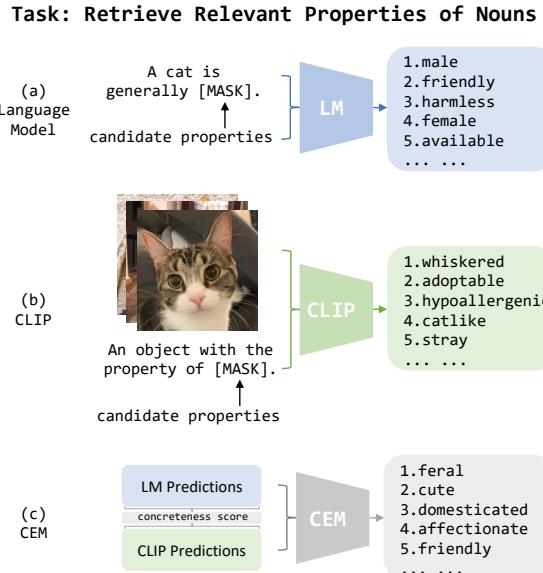


Figure 1: Our task is to retrieve relevant properties of nouns from a set of candidates. We tackle the task via (a) Language Model to fill the mask; (b) Use CLIP to compute the similarity between the properties and images of the noun; (c) Concreteness Ensemble Model (CEM) to ensemble language and CLIP predictions through the concreteness scores of properties.

communication (Lazaridou et al., 2016). Furthermore, identifying noun properties can contribute to better modeling concepts and entities, learning affordances (i.e., defining the possible uses of an object based on its qualities or properties), and understanding models’ knowledge about the world.

Models that combine different modalities provide a sort of grounding which helps to alleviate the reporting bias problem (Kiela et al., 2014; Lazaridou et al., 2015; Zhang et al., 2022). For example, multimodal models are better at predicting color attributes compared to text-based language models (Paik et al., 2021; Norlund et al., 2021). Furthermore, visual representations of concrete objects improve performance in downstream NLP tasks (Hewitt et al., 2018). Inspired by this line of work,

*Equal Contribution.

we expect concrete visual properties of nouns to be more accessible through images, and text-based language models to better encode abstract semantic properties. We propose an ensemble model which combines information from these two sources for English noun property identification.

We frame property identification as a ranking task, where relevant properties for a noun need to be retrieved from a set of candidate properties found in association norm datasets (McRae et al., 2005; Devereux et al., 2014; Norlund et al., 2021). We experiment with text-based language models (Devlin et al., 2019; Radford et al., 2019; Liu et al., 2019) and with CLIP (Radford et al., 2021) which we query using a slot filling task, as shown in Figures 1(a) and (b). Our ensemble model (Figure 1(c)) combines the strengths of language and vision models, by specifically privileging one or the other type of representation depending on the concreteness of the processed properties (Brysbaert et al., 2014). Given that concrete properties are characterized by a higher degree of imageability (Friendly et al., 1982), our model trusts the visual model for perceptual, highly concrete properties (e.g., color adjectives: *red*, *green*), and the language model for abstract properties (e.g., *free*, *infinite*). Our results confirm that CLIP can identify nouns’ perceptual properties better than language models, which contain higher quality information about abstract properties. Our ensemble model, which combines the two sources of knowledge, outperforms the individual models on the property ranking task by a significant margin.

2 Related Work

Probing has been widely used in previous work for exploring the semantic knowledge that is encoded in language models. A common approach has been to convert the facts, properties, and relations found in external knowledge sources into “fill-in-the-blank” cloze statements, and to use them to query language models. Apidianaki and Garí Soler (2021) do so for nouns’ semantic properties and highlight how challenging it is to retrieve this kind of information from BERT representations (Devlin et al., 2019). Furthermore, slightly different prompts tend to retrieve different semantic information (Ettinger, 2020), compromising the robustness of semantic probing tasks. We propose to mitigate these problems by also relying on images.

Features extracted from different modalities can

complement the information found in texts. Multimodal distributional models, for example, have been shown to outperform text-based approaches on semantic benchmarks (Silberer et al., 2013; Bruni et al., 2012, 2014; Lazaridou et al., 2015). Similarly, ensemble models that integrate multimodal and text-based models outperform models that only rely on one modality in tasks such as visual question answering (Tsimpoukelli et al., 2021; Alayrac et al., 2022; Yang et al., 2021b), visual entailment (Song et al., 2022), reading comprehension, natural language inference (Zhang et al., 2021; Kiros et al., 2018), text generation (Su et al., 2022), word sense disambiguation (Barnard and Johnson, 2005), and video retrieval (Yang et al., 2021a). We extend this investigation to noun properties identification.

We propose a novel noun property retrieval model which combines information from language and vision models, and tunes their respective contributions based on property concreteness (Brysbaert et al., 2014). Concreteness is a graded notion that strongly correlates with the degree of imageability (Friendly et al., 1982; Byrne, 1974); concrete words generally tend to refer to tangible objects that the senses can easily perceive (Paivio et al., 1968). We extend this idea to noun properties and hypothesize that vision models would have better knowledge of perceptual, and more concrete, properties (e.g., *red*, *flat*, *round*) than text-based language models, which would better capture abstract properties (e.g., *free*, *inspiring*, *promising*). We evaluate our model using concreteness scores automatically predicted by a regression model (Charbonnier and Wartena, 2019), and compare to its performance with manual (gold) concreteness ratings (Brysbaert et al., 2014). In previous work, concreteness was measured based on the idea that abstract concepts relate to varied and composite situations (Barsalou and Wiemer-Hastings, 2005). Consequently, visually grounded representations of abstract concepts (e.g., *freedom*) should be more complex and diverse than those of concrete words (e.g., *dog*) (Lazaridou et al., 2015; Kiela et al., 2014). Lazaridou et al. (2015) specifically measure the entropy of the vectors induced by multimodal models which serve as an expression of how varied the information they encode is. They demonstrate that the entropy of the multimodal vectors strongly correlates with the degree of abstractness of words.

3 Experimental Setup

3.1 Task Formulation

Given a noun \mathcal{N} and a set of candidate properties \mathbb{P} , a model needs to select the properties $\mathbb{P}_{\mathcal{N}} \subseteq \mathbb{P}$ that apply to \mathcal{N} . The candidate properties are the set of all adjectives retained from a resource (cf. Section 3.2), which characterize different nouns. A model needs to rank properties that apply to \mathcal{N} higher than properties that apply to other nouns in the resource. We consider that a property correctly characterizes a noun, if it has been proposed for that noun by the annotators.

3.2 Datasets

FEATURE NORMS: The [McRae et al. \(2005\)](#) dataset contains feature norms for 541 objects annotated by 725 participants. We follow [Apidianaki and Garí Soler \(2021\)](#) and only use the IS_ADJ features of noun concepts, where the adjective describes a noun property. In total, there are 509 noun concepts with at least one IS_ADJ feature, and 209 unique properties. The FEATURE NORMS dataset contains both perceptual properties (e.g., *tall, fluffy*), and non-perceptual ones (e.g., *intelligent, expensive*).

MEMORY COLORS: The dataset contains 109 nouns with an associated image and its corresponding prototypical color (there are 11 colors in total) ([Norlund et al., 2021](#)). The data were scraped from existing knowledge bases on the web.

CONCEPT PROPERTIES: This dataset was created at the Centre for Speech, Language and Brain ([Devereux et al., 2014](#)). It contains concept property norm annotations collected from 30 participants. The data comprise 601 nouns with 400 unique properties. We keep aside 50 nouns (which are not in FEATURE NORMS and MEMORY COLORS) as our development set (dev). We use the dev for prompt selection and hyper-parameter tuning. We call the rest of the dataset CONCEPT PROPERTIES-test and use it for evaluation.

CONCRETENESS DATASET: The [Brysbaert et al. \(2014\)](#) dataset contains manual concreteness ratings for 37,058 English word lemmas and 2,896 two-word expressions, gathered through crowdsourcing. The original concreteness scores range from 0 to 5. We map them to $[0, 1]$ by dividing each score by 5.

Dataset	# \mathcal{N} s	# \mathcal{P} s	$\mathcal{N}\text{-}\mathcal{P}$ pairs	\mathcal{P} s per \mathcal{N}
FEATURE NORMS	509	209	1592	3.1
CONCEPT PROPERTIES	601	400	3983	6.6
MEMORY COLORS	109	11	109	1.0

Table 1: Statistics of the ground-truth datasets. We show the number of nouns (# \mathcal{N} s), properties (# \mathcal{P} s) and noun-property pairs ($\mathcal{N}\text{-}\mathcal{P}$ pairs), as well as the average number of properties per noun in each dataset.

3.3 Models

3.3.1 Language Models (LMs)

We query language models about their knowledge of noun properties using cloze-style prompts (cf. Appendix A.1). These contain the nouns in singular or plural form, and the [MASK] token at the position where the property should appear (e.g., “*Strawberries are [MASK]*”). A language model assigns a probability score to a candidate property by relying on the tokens preceding and following the [MASK] token, $\mathbf{W}_{\setminus t} = (w_1, \dots, w_{t-1}, w_{t+1}, \dots, w_{|\mathbf{W}|})$:

$$\text{Score}_{\text{LM}}(\mathcal{P}) = \log P_{\text{LM}}(w_t = \mathcal{P} | \mathbf{W}_{\setminus t}, \Theta) \quad (1)$$

where Θ denotes the model parameters. We experiment with BERT-LARGE ([Devlin et al., 2019](#)), ROBERTA-LARGE ([Liu et al., 2019](#)), GPT2-LARGE ([Radford et al., 2019](#)) and GPT3-DAVINCI, which have been shown to deliver impressive performance in Natural Language Understanding tasks ([Yamada et al., 2020; Takase and Kiyono, 2021; Aghajanyan et al., 2021](#)).

Our property ranking setup allows to consider multi-token adjectives² (properties) which were excluded from open-vocabulary masking experiments ([Petroni et al., 2019; Bouraoui et al., 2020; Apidianaki and Garí Soler, 2021](#)). Since the candidate properties are known, we can obtain a score for a multi-token property composed of k pieces ($\mathcal{P} = (w_t, \dots, w_{t+k})$, $k \geq 1$) by taking the average of the scores assigned by the LM to its tokens:

$$\text{Score}_{\text{LM}}(\mathcal{P}) = \frac{1}{k} \sum_{i=0}^k \log P_{\text{LM}}(w_{t+i} | \mathbf{W}_{\setminus t}, \Theta) \quad (2)$$

We report the results in Appendix D.3 and show that our model is better than other models at retrieving multi-token properties.

¹We also experiment with the Unidirectional Language Model (ULM) which yields the probability of the masked token conditioned on the past tokens $\mathbf{W}_{<t} = (w_1, \dots, w_{t-1})$:

²BERT-type models split some words into multiple word pieces during tokenization (e.g., *colorful* → *['color', 'ful']*).

3.3.2 Multimodal Language Models (MLMs)

Vision Encoder-Decoder MLMs are language models conditioned on other modalities than text, for example images. For each noun \mathcal{N} in our datasets, we collect a set of images \mathbb{I} from the web.³ We probe a MLM similarly to LMs, using the same set of prompts. An MLM yields the score for each property given an image $i \in \mathbb{I}$ using Formula 3.

$$\text{Score}_{\text{MLM}}(\mathcal{P}, i) = \log P_{\text{MLM}}(w_t = \mathcal{P} | \mathbf{W}_{\setminus t}, i, \Theta) \quad (3)$$

In addition to the context $\mathbf{W}_{\setminus t}$ and model parameters Θ , the MLM conditions on the image i . Then we aggregate over all the images \mathbb{I} for the noun \mathcal{N} to get the score for the property.

$$\text{Score}_{\text{MLM}}(\mathcal{P}) = \frac{1}{|\mathbb{I}|} \sum_{i \in \mathbb{I}} \text{Score}_{\text{MLM}}(\mathcal{P}, i) \quad (4)$$

We select the Transformer-based (Vaswani et al., 2017) ViLT model (Kim et al., 2021) as our MLM. ViLT uses the same tokenizer as BERT and is pretrained on the Google Conceptual Captions (GCC) dataset which contains more than 3 million image-caption pairs for about 50k words (Sharma et al., 2018). Most other vision-language datasets contain a significantly smaller vocabulary (10k words).⁴ In addition, ViLT requires minimal image pre-processing and is an open visual vocabulary model.⁵ This contrasts with other multimodal architectures which require visual predictions before passing the images on to the multimodal layers (Li et al., 2019; Lu et al., 2019; Tan and Bansal, 2019) and have been shown to only marginally surpass text-only models (Yun et al., 2021).

CLIP We also use the CLIP vision-language model which is pretrained on 400M image-caption pairs (Radford et al., 2021). CLIP is trained to align the embedding spaces learned from images and text, using contrastive loss as a learning objective. The CLIP model integrates a text encoder f_T and a visual encoder f_V which separately encode the text and image to vectors with the same dimension. Given a batch of image-text pairs, CLIP maximizes the cosine similarity for matched pairs while minimizing the cosine similarity for unmatched pairs.

³More details about the image collection procedure are given in Section 3.5.

⁴The vocabulary size is much smaller than in BERT-like language models which are trained on a minimum of 8M words.

⁵Open visual vocabulary models do not need elaborate image pre-processing via an image detection pipeline. As such, they are not restricted to the object classes that are recognized by the pre-processing pipeline.

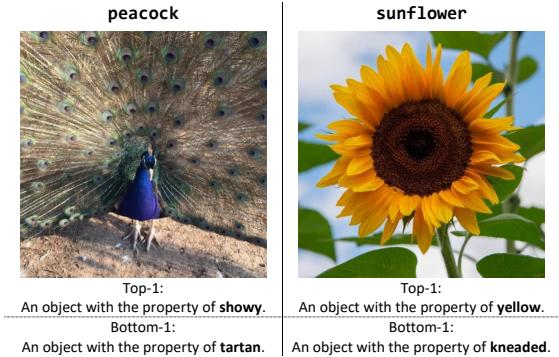


Figure 2: Examples of Top-1 and Bottom-1 prompts ranked by CLIP.

We use CLIP to compute the cosine similarity of an image $i \in \mathbb{I}$ and this text prompt ($s_{\mathcal{P}}$): “*An object with the property of [MASK]*”, where the [MASK] token is replaced with a candidate property \mathcal{P} . The score for each property $\mathcal{P} \in \mathbb{P}$ is the mean similarity between the sentence prompt $s_{\mathcal{P}}$ and all images $i \in \mathbb{I}$:

$$\text{Score}_{\text{CLIP}}(\mathcal{P}) = \frac{1}{|\mathbb{I}|} \sum_{i \in \mathbb{I}} \cos(f_T(s_{\mathcal{P}}), f_V(i)) \quad (5)$$

This score serves to rank the candidate properties according to their relevance for a specific noun. Figure 2 shows the most and least relevant properties for the nouns *peacock* and *sunflower*.

3.3.3 Concreteness Ensemble Model (CEM)

The concreteness score for a property guides CEM towards “trusting” the language or the vision model more. We propose two CEM flavors which we describe as CEM-PRED and CEM-GOLD. CEM-PRED uses the score ($c_{\mathcal{P}} \in [0, 1]$) that is proposed by our concreteness prediction model for every candidate property $\mathcal{P} \in \mathbb{P}$, while CEM-GOLD uses the score for \mathcal{P} in the Brysbaert et al. (2014) dataset.⁶ If there is no gold score for a property, we use the score of the word with the longest matching subsequence in the dataset. Both CEMs combine the rank of \mathcal{P} proposed by the language model (Rank_{LM}) and by CLIP (Rank_{CLIP}) through a weighted sum which is controlled by the concreteness score, $c_{\mathcal{P}}$:

$$\begin{aligned} \text{Rank}_{\text{CEM}}(\mathcal{P}) &= (1 - c_{\mathcal{P}})\text{Rank}_{\text{LM}}(\mathcal{P}) \\ &\quad + c_{\mathcal{P}} \cdot \text{Rank}_{\text{CLIP}}(\mathcal{P}) \end{aligned} \quad (6)$$

⁶Properties in MEMORY COLORS have the highest average concreteness scores (0.82), followed by properties in FEATURE NORMS (0.64) and CONCEPT PROPERTIES (0.62).

3.3.4 Concreteness Prediction Model

We generate concreteness scores using the model of Charbonnier and Wartena (2019) with FastText embeddings (Bojanowski et al., 2017). The model

Model	Prompt Selected
BERT	Most [NOUN-plural] are [MASK].
RoBERTa	A/An [NOUN-singular] is generally [MASK].
GPT-2	Most [NOUN-plural] are [MASK].
ViLT	[NOUN-plural] are [MASK].
CLIP	An object with the property of [MASK].

Table 2: The prompt template selected for each model.

leverages part-of-speech and suffix features to predict concreteness in a classical regression setting. We train the model on the 40k concreteness dataset (Brysbaert et al., 2014), excluding the 425 adjectives found in our evaluation datasets. The model obtains a high Spearman ρ correlation of 0.76 with the ground truth scores of the adjectives in our test sets, showing that automatically predicted scores are a good alternative to manually defined ones.

3.3.5 Baselines

We compare the predictions of the language, vision, and ensemble models to those of three baseline methods.

RANDOM : Generates a RANDOM property ranking for each noun.

GLOVE : Ranking based on the cosine similarity of the GLOVE embeddings (Pennington et al., 2014) of the noun and the property.

GOOGLE NGRAM: Ranking by the bigram frequency of each noun-property pair in Google n-grams (Brants and Franz, 2009). If a noun-property pair does not appear in the corpus, we assign to it a frequency of 0.

3.4 Evaluation Metrics

We evaluate the property ranking proposed by each model using the top-K Accuracy (A@K), top-K recall (R@K), and Mean Reciprocal Rank (MRR) metrics. A@K is defined as the percentage of nouns for which **at least one** ground-truth property is among the top-K predictions (Ettinger, 2020). R@K shows the proportion of ground-truth properties retrieved in the top-K predictions. We report the average R@K across all nouns in a dataset. MRR stands for the ground-truth properties’ average reciprocal ranks (more precisely, the inverse of the rank, $\frac{1}{\text{rank}}$). For all three metrics, high scores are better.

3.5 Implementation Details

Prompt Selection We evaluate the performance of BERT-LARGE, ROBERTA-LARGE, GPT-2-LARGE, and ViLT on the dev set (cf. Section 3.2) using the prompt templates proposed by Apidianaki and Garí Soler (2021). For CLIP, we handcraft a set of prompts that are close to the format that was recommended in the original paper (Radford et al., 2021) and evaluate their performance on the dev set. We choose the prompt that gives the highest performance on the dev set for each model, and use it for all our experiments.⁷ Table 2 lists the prompt templates selected for each model.

Image Collection We collect images for the nouns in our datasets using the Bing Image Search API, an image query interface widely used for research purposes (Kiela et al., 2016; Mostafazadeh et al., 2016).⁸ We again use the dev set to determine the number of images needed for each noun. We find that good performance can be achieved with only ten images (cf. Figure 7 in Appendix B.1). Adding more images increases the computations needed without significantly improving the performance. Therefore, we set the number of images per noun to ten for all vision models and experiments.

Model Implementation All LMs and MLMs are built on the huggingface API.⁹ The CLIP model is adapted from the official repository.¹⁰ CEM ensembles the ROBERTA-LARGE and CLIP-ViT/L14 models. The experiments were run on Quadro RTX 6000 24GB and all models are run in inference mode with no experiment taking longer than 1 GPU hour including image encodings.

4 Evaluation

4.1 Property Ranking Task

Table 3 shows the results obtained by the LMs, the MLMs and our CEM model on the FEATURE NORMS, CONCEPT PROPERTIES-test¹¹ and MEMORY COLORS datasets. The two flavors of CEM (CEM-PRED and CEM-GOLD) outperform all other models with a significant margin across datasets. Interestingly, CEM-PRED performs better than CEM-GOLD on the CONCEPT

⁷See Appendix A for details.

⁸We use the bing-image-downloader API.

⁹<https://huggingface.co>

¹⁰<https://github.com/openai/CLIP>

¹¹Contains all nouns in CONCEPT PROPERTIES except from the ones in the CONCEPT PROPERTIES-dev set.

Model	# Param	Img	FEATURE NORMS					CONCEPT PROPERTIES-test					MEMORY COLORS*		
			A@1	A@5	R@5	R@10	MRR	A@1	A@5	R@5	R@10	MRR	A@1	A@2	A@3
RANDOM	0	X	1.0	2.4	0.7	1.4	.018	0.2	3.8	0.5	1.7	.014	11.9	20.2	25.7
GLOVE	0	X	16.3	42.2	16.4	26.6	.124	18.5	46.6	9.5	16.4	.078	28.4	45.0	60.1
GOOGLE-NGRAM	0	X	23.4	65.2	31.5	47.7	.192	27.9	72.1	18.5	30.3	.122	44.0	63.3	69.7
BERT-LARGE	345M	X	27.3	60.3	29.4	43.6	.194	31.4	72.1	18.2	29.2	.123	44.0	57.8	67.9
ROBERTA-LARGE	354M	X	24.6	63.1	30.2	46.3	.188	34.1	79.1	22.4	34.8	.138	48.6	61.5	67.9
GPT2-LARGE	1.5B	X	22.0	60.7	28.4	42.9	.173	35.6	77.0	21.0	32.4	.136	44.0	57.8	67.9
GPT3-DAVINCI	175B	X	37.9	61.5	31.8	44.2	-**	47.0	72.2	20.1	29.7	-**	74.3	82.6	84.4
VILT	135M	✓	27.9	56.0	26.2	40.1	.185	34.5	63.2	15.7	23.7	.118	74.3	-	-
CLIP-VIT/L14	427M	✓	28.5	61.7	29.4	42.7	.197	29.2	63.0	15.0	24.9	.113	84.4	91.7	97.2
CEM-GOLD	781M	✓	40.1	76.2	40.0	53.3	.252	48.3	84.6	26.9	39.1	.171	88.1	96.3	97.2
CEM-PRED	781M	✓	39.9	75.8	40.0	52.5	.251	49.9	85.8	28.1	40.0	.175	88.1	96.3	98.1

Table 3: Results obtained on the three datasets. The best result for each metric is marked in **boldface**.

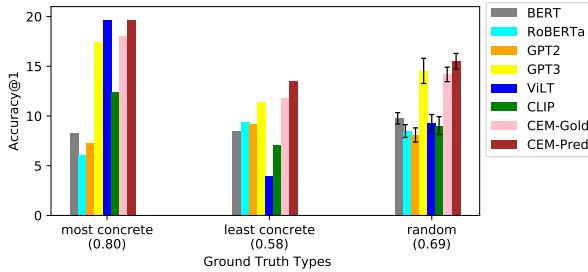


Figure 3: Top-1 Accuracy for the FEATURE NORMS properties filtered by concreteness. The average concreteness score for each band is given on the x-axis. The error bars in the random category represent the standard deviation on 10 trials.

PROPERTIES-test dataset. This may be due to the fact that 49 properties in this dataset do not have ground-truth concreteness scores (vs. only 15 properties in FEATURE NORMS). For these properties, CEM-GOLD selects the score of the word with the longest matching subsequence, as explained in Section 3.3.3. Our prediction model probably approximates concreteness better in these cases, contributing to higher scores for CEM-PRED.

We notice that the GOOGLE-NGRAM baseline performs well on FEATURE NORMS, with results on par or superior to big LMs. The somewhat lower results obtained on CONCEPT PROPERTIES-test might be due to the higher number of properties in this dataset, which makes the ranking task more challenging.¹² There is also a higher number of noun-property pairs that are not found in Google Bigrams and which are assigned a zero score.¹³

The MEMORY COLORS dataset associates each noun with a *single* color so we only report Accuracy at top-K (last three columns of Table 3). We can compare these scores to a previous baseline, the

¹²The mean number of properties per noun in CONCEPT PROPERTIES is 6.6, and 3.1 in FEATURE NORMS.

¹³26% of the pairs in CONCEPT PROPERTIES vs. 15% for FEATURE NORMS.

top-1 Accuracy reported by Norlund et al. (2021) for the CLIP-BERT model which is 78.5.¹⁴ CEM-PRED and GOLD both do better on this dataset.

Noun	Property	
	most concrete	least concrete
dandelion	yellow	annoying
cougar	brown	vicious
wand	round	magical
spear	sharp	dangerous
pyramid	triangular	mysterious

Table 4: Examples of nouns with their most and least concrete properties in FEATURE NORMS.

GPT-3 gets much higher scores than the other three language models on this task, with a top-1 Accuracy of 74.3, but is outperformed by CLIP and CEM. Note that MRR does not apply to GPT-3 since it generates (instead of reranking) properties (cf. Appendix A.3).

The multimodal model with the lowest performance, ViLT, is as good as GPT-3, and a slight improvement is obtained with CLIP. CEM-PRED and CEM-GOLD present a clear advantage, achieving a top-1 Accuracy of 88.1. Although ROBERTA gets very low Accuracy on MEMORY COLORS, it does not hurt performance when combined with CLIP in our CEM-GOLD model. This is because the color properties in this dataset have high concreteness scores (0.82 on average), so CEM-GOLD relies mainly on CLIP which works very well in this setting. CEM-GOLD makes the same top-1 predictions as CLIP for 95 nouns (out of 109), while only 50 nouns are assigned the same color by CEM-GOLD and ROBERTA.

¹⁴We cannot calculate the other scores because CLIP-BERT has not been made available. In this model, a CLIP encoded image is appended to BERT’s tokenized input before fine-tuning with a masked language model objective on 4.7M captions paired with 2.9M images. For more details refer to (Norlund et al., 2021).

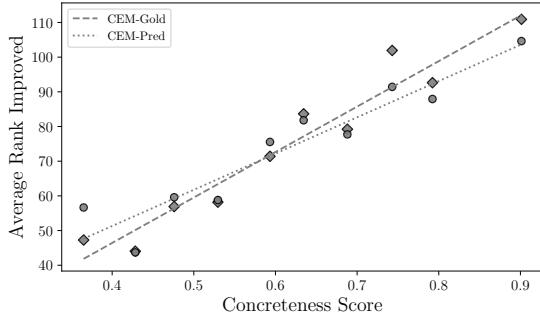


Figure 4: The average Rank Improvement (RI) score for properties in the CONCEPT PROPERTIES-test grouped in ten bins according to their concreteness. The higher the concreteness score of the properties in a bin, the bigger the improvement brought by CEM-GOLD and CEM-PRED over ROBERTA.

4.2 Additional Analysis

Concreteness level. We compare the performance of each model for properties at different concreteness levels. From the properties available for a noun in FEATURE NORMS,¹⁵ we keep a single property as our ground truth: (a) **most concrete**: the property with the highest concreteness score in the Brysbaert et al. (2014) lexicon; (b) **least concrete**: the property with the lowest concreteness score; (c) **random**: a randomly selected property¹⁶. Figure 3 shows the top-1 Accuracy of the models for these properties. Examples of nouns with their most and least concrete properties are given in Table 4. The results of this experiment confirm our initial assumption that MLMs (e.g., CLIP and ViLT) better capture concrete properties, and LMs (e.g., ROBERTA and GPT-2) are better at identifying abstract ones. GPT-3 is the only LM that performs better for concrete over abstract properties, while still falling behind both CEM variations.

Rank Improvement. We investigate the relationship between the performance of CEM and the concreteness score of the properties in CONCEPT PROPERTIES-test. We measure the rank improvement (RI) of a property (\mathcal{P}) as follows:

$$RI(\mathcal{P}) = \text{Rank}_{\text{CEM}}(\mathcal{P}) - \text{Rank}_{\text{RoBERTa}}(\mathcal{P}) \quad (7)$$

A high RI score for \mathcal{P} means that its rank is improved in CEM compared to ROBERTA. We calculate the RI for properties at different concreteness levels. We sort the 400 properties in CON-

¹⁵In this experiment, we use 411 nouns (out of 509) from FEATURE NORMS which have at least two properties.

¹⁶We report the mean and standard deviation on 10 trial.

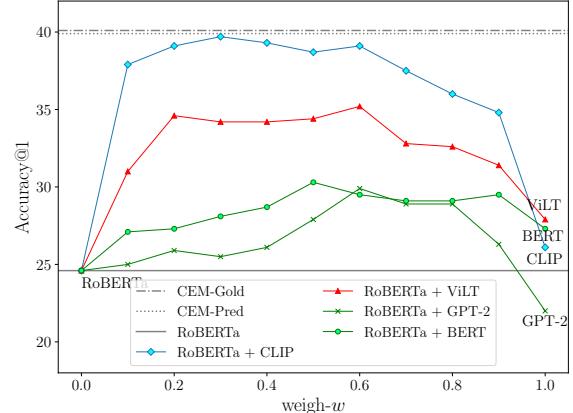


Figure 5: Top-1 Accuracy obtained by different ensemble models on the FEATURE NORMS dataset. The x-axis shows the weight used to interpolate two models. The straight dashed and dotted lines are the top-1 Accuracy of CEM-GOLD (40.1%) and CEM-PRED (39.9%) respectively.

CEPT PROPERTIES-test by increasing concreteness score, and group them into ten bins of 40 properties each. We find a clear positive relationship between the average RI and concreteness scores within each bin, as shown in Figure 4. This explains why CEM improves more on concrete properties.

Ensemble Weight Selection. We explore whether a dynamic concreteness-based ensemble weight outperforms a fixed one. We experiment with different model combinations (ROBERTA with BERT, GPT-2, and ViLT) with an interpolation weight w that takes values in the range [0,1]. If the weight is close to 0, CEM relies more on ROBERTA; if it is 1, CEM relies more on the second model.

$$\begin{aligned} \text{Rank}_{\text{combine}}(\mathcal{P}) &= (1 - w) \cdot \text{Rank}_{\text{RoBERTa}}(\mathcal{P}) \\ &\quad + w \cdot \text{Rank}_{\text{other model}}(\mathcal{P}) \end{aligned} \quad (8)$$

We also run the best performing ROBERTA + CLIP combination again using weights fixed in this way (i.e. without recourse to the properties’ concreteness score as in CEM-PRED and in CEM-GOLD). Note that we do not expect the combination of two text-based LMs to improve Accuracy a lot compared to ROBERTA alone. Our intuition is confirmed by the results obtained on FEATURE NORMS and shown in Figure 5.

The dashed and dotted straight lines in the figure represent the top-1 Accuracy of CEM-GOLD and CEM-PRED, respectively, when the weights used are not the ones on the x-axis, but the gold

Noun	Model	Top-3 Properties
swan	RoBERTA	male, white, black
	CLIP	white, graceful, gentle
	GPT-3	graceful, regal, stately
	CEM-GOLD	white, large, graceful
ox	CEM-PRED	white, endangered, graceful
	RoBERTA	male, white, black
	CLIP	endangered, wild, harvested
	GPT-3	strong, muscular, brawny
orange	CEM-GOLD	large, wild, friendly
	CEM-PRED	large, wild, hairy
	RoBERTA	edible, yellow, orange
	CLIP	orange, citrus, juicy
orange	GPT-3	tart, acidic, sweet
	CEM-GOLD	orange, edible, healthy
	CEM-PRED	orange, edible, citrus
	cape	black, white, fashionable
cape	CLIP	cozy, dressy, cold
	GPT-3	tart, acidic, sweet
	CEM-GOLD	fashionable, dark, grey
	CEM-PRED	fashionable, grey, dark

Table 5: Top-3 properties proposed by different models for nouns in FEATURE NORMS.

and predicted concreteness scores (cf. Equation 6). To further highlight the importance of concreteness in interpolating the models, we provide additional results and comparisons in Appendix C.2. Note that CEM-GOLD and CEM-PRED have highly similar performance and actual output: on average, they propose 4.35 identical properties at top-5 on FEATURE NORMS, and 4.41 on CONCEPT PROPERTIES-test.

We observe a slight improvement in top-1 Accuracy (5%) when ensembling two text-based LMs (RoBERTA + BERT, RoBERTA + GPT-2). Text-based LMs have similar output distributions, hence combining them does not change the final distribution much. The RoBERTA + ViLT ensemble model achieves higher performance due to the interpolation with an image-based model, but it does not reach the Accuracy of CEM (RoBERTA + CLIP). The ViLT model gets lower performance than CLIP when combined with RoBERTA, because it was exposed to much less data than CLIP during training (400 M vs. 30 M). Finally, we notice that the best performance of RoBERTA + CLIP with fixed weight is slightly lower than that of the CEM models. This indicates that using a fixed weight to ensemble two models hurts performance compared to calibrating their mutual contribution using the concreteness score. Another advantage of the concreteness score is that it is more transferable since it does not require tuning on new datasets.

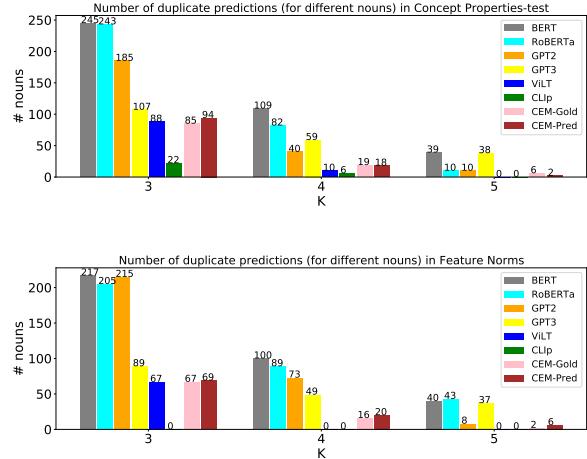


Figure 6: Number of nouns for which a model proposed the same properties in top-K, in the same order. The considered values of K are given on the x axis.

Properties Quality. Table 5 shows a random sample of the top 3 predictions by each model for nouns from CONCEPT PROPERTIES-test. We notice that the properties proposed by both flavors of CEM are both perceptual and abstract, due to their access to both a language and a vision model. We further observe that CEM retrieves rarer words, and more varied properties for different nouns, in comparison to other language models.¹⁷

Figure 6 shows the number of nouns which got the same top-K predictions by each model. For example GPT-3 predicts [*tart, acidic, sweet, juicy, smooth*] for 20 different nouns in the same order; RoBERTA predicts [*male, healthy, white, black, small*] for both *mittens* and *penguin*, and [*male, black, white, brown, healthy*] for *owl* and *flamingo*. We observe that both flavors of CEM are less likely to retrieve the same top-K predictions for a noun than other language models, CEM combines the variability and Accuracy of CLIP with the benefits of text-based models, which are exposed to large volumes of texts during pre-training.

5 Conclusion

We explore the task of retrieving noun’s semantic properties by comparing the performance of language models and multimodal models. Our noun property ranking model CEM leverages knowledge from vision and language models based on concreteness. The results show that the combination of RoBERTA and CLIP outperforms powerful text-

¹⁷Details on the frequency of the properties retrieved by each model are reported in Appendix D.1. We provide more randomly sampled qualitative examples in Appendix D.4.

based language models (such as GPT-3) with significant margins in three evaluation datasets. Our methodology outperforms alternative ensembling techniques, confirming our hypothesis that concrete properties are more accessible through images, and abstract properties through text. The Accuracy scores obtained on the larger datasets show that there is still room for improvement for this challenging task.

6 Limitations

Our experiments address concreteness at the lexical level, specifically using the scores assigned to adjectives in an external resource (Brysbaert et al., 2014) or predicted using (Charbonnier and Wartena, 2019). Another option would be to use the concreteness of the noun phrases formed by the adjectives and the nouns they modify. We would expect this to be different than that of adjectives in isolation since the concreteness of the nouns has an impact on that of the resulting phrase (e.g., *useful knife* vs. *useful idea*). We were not able to evaluate the impact of noun phrase concreteness on property prediction because the property datasets used in our experiments mostly contain concrete nouns. Another limitation of our methodology is the reliance on pairing images with nouns. In particular, we use a search engine to retrieve images corresponding to nouns in order to get grounded predictions from the vision model. Finally, we only evaluate our methodology in English and we leave it to future work to experiment with different languages either through the collection of multi-lingual semantic association datasets and/or the translation of existing ones. We did not pursue this extension for this paper as **MULTILINGUAL CLIP** model weights only became available very recently.

References

- Armen Aghajanyan, Anchit Gupta, Akshat Shrivastava, Xilun Chen, Luke Zettlemoyer, and Sonal Gupta. 2021. Muppet: Massive Multi-task Representations with Pre-Finetuning. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 5799–5811.
- Jean-Baptiste Alayrac, Jeff Donahue, Pauline Luc, Antoine Miech, Iain Barr, Yana Hasson, Karel Lenc, Arthur Mensch, Katie Millican, Malcolm Reynolds, et al. 2022. Flamingo: a visual language model for few-shot learning. *arXiv preprint arXiv:2204.14198*.
- Marianna Apidianaki and Aina Garí Soler. 2021. ALL dolphins are intelligent and SOME are friendly: Prob-
ing BERT for nouns’ semantic properties and their prototypicality. In *Proceedings of the Fourth BlackboxNLP Workshop on Analyzing and Interpreting Neural Networks for NLP*, pages 79–94, Punta Cana, Dominican Republic. Association for Computational Linguistics.
- Kobus Barnard and Matthew Johnson. 2005. Word sense disambiguation with pictures. *Artificial Intelligence*, 167(1-2):13–30.
- Lawrence W. Barsalou and Katja Wiemer-Hastings. 2005. Situating abstract concepts. pages 129–163.
- Piotr Bojanowski, Edouard Grave, Armand Joulin, and Tomas Mikolov. 2017. Enriching word vectors with subword information. *Transactions of the Association for Computational Linguistics*, 5:135–146.
- Zied Bouraoui, José Camacho-Collados, and Steven Schockaert. 2020. Inducing Relational Knowledge from BERT. In *The Thirty-Fourth AAAI Conference on Artificial Intelligence*, pages 7456–7463, New York, NY, USA. AAAI Press.
- Thorsten Brants and Alex Franz. 2009. Web 1T 5-gram, 10 European languages version 1. *Linguistic Data Consortium, Philadelphia*.
- Elia Bruni, Gemma Boleda, Marco Baroni, and Nam-Khanh Tran. 2012. Distributional semantics in technicolor. In *Proceedings of the 50th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 136–145, Jeju Island, Korea. Association for Computational Linguistics.
- Elia Bruni, Nam Khanh Tran, and Marco Baroni. 2014. Multimodal Distributional Semantics. *J. Artif. Int. Res.*, 49(1):1–47.
- Marc Brysbaert, Amy Beth Warriner, and Victor Kuperman. 2014. Concreteness ratings for 40 thousand generally known english word lemmas. *Behavior research methods*, 46(3):904–911.
- Brian Byrne. 1974. Item concreteness vs spatial organization as predictors of visual imagery. *Memory & Cognition*, 2(1):53–59.
- Jean Charbonnier and Christian Wartena. 2019. Predicting word concreteness and imagery. In *Proceedings of the 13th International Conference on Computational Semantics-Long Papers*, pages 176–187. Association for Computational Linguistics.
- Barry J Devereux, Lorraine K Tyler, Jeroen Geertzen, and Billi Randall. 2014. The Centre for Speech, Language and the Brain (CSLB) concept property norms. *Behavior research methods*, 46(4):1119–1127.
- Jacob Devlin, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2019. BERT: Pre-training of deep bidirectional transformers for language understanding. In *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*, pages 4171–4186, Minneapolis, Minnesota. Association for Computational Linguistics.

- Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers)*, pages 4171–4186, Minneapolis, Minnesota. Association for Computational Linguistics.
- Allyson Ettinger. 2020. What BERT is not: Lessons from a new suite of psycholinguistic diagnostics for language models. *Transactions of the Association for Computational Linguistics*, 8:34–48.
- Michael Friendly, Patricia E Franklin, David Hoffman, and David C Rubin. 1982. The Toronto Word Pool: Norms for imagery, concreteness, orthographic variables, and grammatical usage for 1,080 words. *Behavior Research Methods & Instrumentation*, 14(4):375–399.
- Jonathan Gordon and Benjamin Van Durme. 2013. Reporting Bias and Knowledge Acquisition. In *Proceedings of the 2013 Workshop on Automated Knowledge Base Construction*, AKBC ’13, page 25–30, New York, NY, USA. Association for Computing Machinery.
- Aurélie Herbelot and Eva Maria Vecchi. 2015. Building a shared world: Mapping distributional to model-theoretic semantic spaces. In *Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing*, pages 22–32.
- John Hewitt, Daphne Ippolito, Brendan Callahan, Reno Kriz, Derry Tanti Wijaya, and Chris Callison-Burch. 2018. Learning translations via images with a massively multilingual image dataset. In *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 2566–2576, Melbourne, Australia. Association for Computational Linguistics.
- Douwe Kiela, Felix Hill, Anna Korhonen, and Stephen Clark. 2014. Improving multi-modal representations using image dispersion: Why less is sometimes more. In *Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, pages 835–841, Baltimore, Maryland. Association for Computational Linguistics.
- Douwe Kiela, Anita Lilla Verő, and Stephen Clark. 2016. Comparing data sources and architectures for deep visual representation learning in semantics. In *Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing*, pages 447–456, Austin, Texas. Association for Computational Linguistics.
- Wonjae Kim, Bokyung Son, and Ildoo Kim. 2021. Vilt: Vision-and-language transformer without convolution or region supervision. In *International Conference on Machine Learning*, pages 5583–5594. PMLR.
- Jamie Kiros, William Chan, and Geoffrey Hinton. 2018. Illustrative language understanding: Large-scale visual grounding with image search. In *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 922–933.
- Angeliki Lazaridou, Nghia The Pham, and Marco Baroni. 2015. Combining language and vision with a multimodal skip-gram model. In *Proceedings of the 2015 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*, pages 153–163, Denver, Colorado. Association for Computational Linguistics.
- Angeliki Lazaridou, Nghia The Pham, and Marco Baroni. 2016. The red one!: On learning to refer to things based on discriminative properties. In *Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, pages 213–218, Berlin, Germany. Association for Computational Linguistics.
- Liunian Harold Li, Mark Yatskar, Da Yin, Cho-Jui Hsieh, and Kai-Wei Chang. 2019. Visualbert: A simple and performant baseline for vision and language. *arXiv preprint arXiv:1908.03557*.
- Yinhan Liu, Myle Ott, Naman Goyal, Jingfei Du, Mandar Joshi, Danqi Chen, Omer Levy, Mike Lewis, Luke Zettlemoyer, and Veselin Stoyanov. 2019. Roberta: A robustly optimized bert pretraining approach. *arXiv preprint arXiv:1907.11692*.
- Jiasen Lu, Dhruv Batra, Devi Parikh, and Stefan Lee. 2019. Vilbert: Pretraining task-agnostic visiolinguistic representations for vision-and-language tasks. *Advances in neural information processing systems*, 32.
- Ken McRae, George S Cree, Mark S Seidenberg, and Chris McNorgan. 2005. Semantic feature production norms for a large set of living and nonliving things. *Behavior research methods*, 37(4):547–559.
- Tomas Mikolov, Edouard Grave, Piotr Bojanowski, Christian Puhrsch, and Armand Joulin. 2018. Advances in Pre-Training Distributed Word Representations. In *Proceedings of the International Conference on Language Resources and Evaluation (LREC 2018)*.
- Nasrin Mostafazadeh, Ishan Misra, Jacob Devlin, Margaret Mitchell, Xiaodong He, and Lucy Vanderwende. 2016. Generating natural questions about an image. In *Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 1802–1813, Berlin, Germany. Association for Computational Linguistics.
- Tobias Norlund, Lovisa Hagström, and Richard Johansson. 2021. Transferring knowledge from vision to language: How to achieve it and how to measure it? In *Proceedings of the Fourth BlackboxNLP Workshop on Analyzing and Interpreting Neural Networks for NLP*, pages 149–162, Punta Cana, Dominican Republic. Association for Computational Linguistics.

- Cory Paik, Stéphane Aroca-Ouellette, Alessandro Roncone, and Katharina Kann. 2021. **The World of an Octopus: How Reporting Bias Influences a Language Model’s Perception of Color**. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 823–835, Online and Punta Cana, Dominican Republic. Association for Computational Linguistics.
- Allan Paivio, John C Yuille, and Stephen A Madigan. 1968. Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of experimental psychology*, 76(1p2):1.
- Jeffrey Pennington, Richard Socher, and Christopher D Manning. 2014. Glove: Global vectors for word representation. In *Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)*, pages 1532–1543.
- Fabio Petroni, Tim Rocktäschel, Sebastian Riedel, Patrick Lewis, Anton Bakhtin, Yuxiang Wu, and Alexander Miller. 2019. **Language models as knowledge bases?** In *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)*, pages 2463–2473, Hong Kong, China. Association for Computational Linguistics.
- Alec Radford, Jong Wook Kim, Chris Hallacy, Aditya Ramesh, Gabriel Goh, Sandhini Agarwal, Girish Sastry, Amanda Askell, Pamela Mishkin, Jack Clark, et al. 2021. Learning transferable visual models from natural language supervision. In *International Conference on Machine Learning*, pages 8748–8763. PMLR.
- Alec Radford, Jeffrey Wu, Rewon Child, David Luan, Dario Amodei, Ilya Sutskever, et al. 2019. Language models are unsupervised multitask learners. *OpenAI blog*, 1(8):9.
- Piyush Sharma, Nan Ding, Sebastian Goodman, and Radu Soricut. 2018. Conceptual captions: A cleaned, hypernymed, image alt-text dataset for automatic image captioning. In *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 2556–2565.
- Vered Shwartz and Yejin Choi. 2020. **Do neural language models overcome reporting bias?** In *Proceedings of the 28th International Conference on Computational Linguistics*, pages 6863–6870, Barcelona, Spain (Online). International Committee on Computational Linguistics.
- Carina Silberer, Vittorio Ferrari, and Mirella Lapata. 2013. **Models of semantic representation with visual attributes.** In *Proceedings of the 51st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 572–582, Sofia, Bulgaria. Association for Computational Linguistics.
- Haoyu Song, Li Dong, Weinan Zhang, Ting Liu, and Furu Wei. 2022. CLIP Models are Few-Shot Learners: Empirical Studies on VQA and Visual Entailment. In *Proceedings of the 60th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 6088–6100.
- Xixuan Su, Tian Lan, Yahui Liu, Fangyu Liu, Dani Yogatama, Yan Wang, Lingpeng Kong, and Nigel Collier. 2022. Language Models Can See: Plugging Visual Controls in Text Generation. *arXiv preprint arXiv:2205.02655*.
- Sho Takase and Shun Kiyono. 2021. Lessons on parameter sharing across layers in transformers. *arXiv preprint arXiv:2104.06022*.
- Hao Tan and Mohit Bansal. 2019. **LXMERT: Learning Cross-Modality Encoder Representations from Transformers.** In *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)*, pages 5100–5111.
- Maria Tsimpoukelli, Jacob L Menick, Serkan Cabi, SM Eslami, Oriol Vinyals, and Felix Hill. 2021. Multimodal few-shot learning with frozen language models. *Advances in Neural Information Processing Systems*, 34:200–212.
- Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. Attention is all you need. *Advances in neural information processing systems*, 30.
- Ikuya Yamada, Akari Asai, Hiroyuki Shindo, Hideaki Takeda, and Yuji Matsumoto. 2020. LUKE: Deep Contextualized Entity Representations with Entity-aware Self-attention. In *Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, pages 6442–6454.
- Yue Yang, Joongwon Kim, Artemis Panagopoulou, Mark Yatskar, and Chris Callison-Burch. 2021a. Induce, edit, retrieve: Language grounded multimodal schema for instructional video retrieval. *arXiv preprint arXiv:2111.09276*.
- Yue Yang, Artemis Panagopoulou, Qing Lyu, Li Zhang, Mark Yatskar, and Chris Callison-Burch. 2021b. Visual goal-step inference using wikihow. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 2167–2179.
- Tian Yun, Chen Sun, and Ellie Pavlick. 2021. **Does vision-and-language pretraining improve lexical grounding?** In *Findings of the Association for Computational Linguistics: EMNLP 2021*, pages 4357–4366, Punta Cana, Dominican Republic. Association for Computational Linguistics.
- Chenyu Zhang, Benjamin Van Durme, Zhuowan Li, and Elias Stengel-Eskin. 2022. Visual commonsense in pretrained unimodal and multimodal models. *arXiv preprint arXiv:2205.01850*.

Lisai Zhang, Qingcai Chen, Joanna Siebert, and Buzhou Tang. 2021. Semi-supervised Visual Feature Integration for Language Models through Sentence Visualization. In *Proceedings of the 2021 International Conference on Multimodal Interaction*, pages 682–686.

A Prompt Selection

A.1 Language Model Prompts

In our experiments with language models, we use the 11 prompts proposed by [Apidianaki and Garí Soler \(2021\)](#) for retrieving noun properties. As shown in Table 6, these involve nouns in singular and plural forms. The performance each language model achieves on the CONCEPT PROPERTIES development set with these prompts is given in Table 8. The results reflect that the models’ performance varies significantly with prompts. The best-performing prompt is different for each model. For BERT and GPT-2, the “most + PLURAL” obtains the highest Recall and MRR scores. The best performing prompt for ROBERTA-LARGE is “SINGULAR + generally”, and “PLURAL” for ViLT.

Prompt Type	Prompt Example
SINGULAR	a motorcycle is [MASK].
PLURAL	motorcycles are [MASK].
SINGULAR + usually	a motorcycle is usually [MASK].
PLURAL + usually	motorcycles are usually [MASK].
SINGULAR + generally	a motorcycle is generally [MASK].
PLURAL + generally	motorcycles are generally [MASK].
SINGULAR + can be	a motorcycle can be [MASK].
PLURAL + can be	motorcycles can be [MASK].
most + PLURAL	most motorcycles are [MASK].
all + PLURAL	all motorcycles are [MASK].
some + PLURAL	some motorcycles are [MASK].

Table 6: Prompts used for language models.

A.2 CLIP Prompts

For CLIP, we handcraft ten prompts and report their performance on the CONCEPT PROPERTIES development set in Table 7. Similar to what we observed with language models, CLIP performance is also sensitive to the prompts used. We select for our experiments the prompt “An object with the property of [MASK].”, which obtains the highest average Accuracy and MRR score on the CONCEPT PROPERTIES development set .

Prompt Type	Acc@1	R@5	R@10	MRR
[MASK]	26.0	13.1	21.9	.097
This is [MASK].	28.0	9.6	13.6	.089
A [MASK] object.	22.0	13.2	18.9	.089
This is a [MASK] object.	22.0	12.0	17.2	.087
The item is [MASK].	18.0	7.5	17.2	.074
The object is [MASK].	24.0	10.5	16.2	.088
The main object is [MASK].	24.0	10.3	20.3	.091
An object which is [MASK].	28.0	13.7	19.9	.106
An object with the property of [MASK].	32.0	12.3	20.0	.108

Table 7: Full results of CLIP-ViT/L14 on the CONCEPT PROPERTIES development set.

A.3 GPT-3 Prompts

Since we do not have complete control of GPT-3 at this moment, we treat GPT-3 as a question-answering model using the following prompt in a one-shot example setting:

Use ten adjectives to describe the properties of kiwi:\n1. tart\n2. acidic\n3. sweet\n4. juicy\n5. smooth\n6. fuzzy\n7. green\n8. brown\n9. small\n10. round

Use ten adjectives to describe the properties of [NOUN]:\n

We use the `text-davinci-001` engine of GPT-3 which costs \$0.06 per 1,000 tokens. On average, it costs \$0.007 to generate 10 properties for each noun.

B Implementation of CLIP

B.1 Number of Images

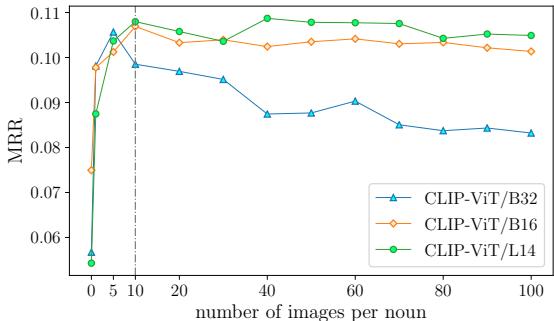


Figure 7: The CLIP performance on CONCEPT PROPERTIES-test development set with a different number of images per noun.

For each noun, we collected 200 images from Bing. Given that it is not practical to use such a high number of images for a large-scale experiment, we investigate the performance of CLIP with different number of images. We first filter the 200 images collected for each noun to remove duplicates. We then sort the remaining images based on the cosine similarity of each image with the sentence “A photo of [NOUN].”.

We pick the top-j images and gradually increase the value of K.¹⁸ Figure 7 shows the MRR obtained by CLIP on the CONCEPT PROPERTIES development set with a varying number of images. We observe that the model’s MRR score increases

¹⁸When K = 0, we use the CLIP text encoder to encode the noun as the image embedding.

Prompt Type	BERT-large			RoBERTa-large			GPT-2-large			ViLT		
	R@5	R@10	MRR	R@5	R@10	MRR	R@5	R@10	MRR	R@5	R@10	MRR
SINGULAR	8.9	17.3	.067	17.1	23.6	.092	14.0	27.5	.097	12.6	18.2	.085
PLURAL	11.5	21.9	.070	10.5	21.1	.085	14.9	23.7	.098	15.5	24.5	.105
SINGULAR + usually	12.7	24.5	.082	15.5	26.5	.098	16.2	25.3	.107	11.8	18.7	.088
PLURAL + usually	14.4	27.6	.107	13.3	23.7	.106	17.8	24.6	.113	15.6	21.7	.091
SINGULAR + generally	14.3	23.6	.087	17.7	27.9	.119	18.7	29.2	.114	12.7	19.4	.083
PLURAL + generally	15.0	26.7	.097	16.0	25.3	.105	17.4	26.7	.128	9.8	18.6	.075
SINGULAR + can be	12.4	23.9	.102	14.7	22.7	.090	14.3	24.7	.105	9.2	14.1	.056
PLURAL + can be	16.0	26.4	.107	12.1	17.7	.073	10.2	18.3	.096	10.0	14.2	.060
most + PLURAL	16.7	27.3	.107	12.6	25.7	.098	20.0	33.4	.122	12.6	20.8	.095
all + PLURAL	13.4	20.5	.083	8.2	13.5	.073	19.6	31.3	.113	14.4	20.4	.103
some + PLURAL	11.2	21.5	.082	16.4	23.5	.100	15.4	31.5	.097	10.7	17.2	.091

Table 8: Full results of language models on the CONCEPT PROPERTIES development set with different prompts. The highest numbers of each column are **bold**. The best prompt for each model is highlighted, selected based on the average performance over all metrics.

	FEATURE NORMS				CONCEPT PROPERTIES -test				Memory Colors		
	Acc@1	R@5	R@10	MRR	Acc@1	R@5	R@10	MRR	Acc@1	Acc@3	Acc@5
CLIP-ViT/B32	24.8	24.8	36.1	.172	27.6	13.0	19.6	.097	83.5	95.4	99.1
CLIP-ViT/B16	25.3	27.4	38.9	.184	28.3	14.3	22.0	.103	87.2	96.3	98.2
CLIP-ViT/L14	26.1	29.2	43.3	.192	29.2	15.0	24.9	.113	82.6	96.3	99.1

Table 9: Performance of CLIP models with different sizes.

with a higher number of images. Nevertheless, the improvement is marginal when the number of images is higher than ten and starts to overfit when the number is higher than 20. Therefore, we decided to use ten images for all experiments involving CLIP.

B.2 CLIP Size

We evaluate three sizes of CLIP, from small to large: CLIP-ViT/B16, CLIP-ViT/B32, and CLIP-ViT/L14. As shown in Figure 7, the performance positively correlates with the model size. The largest model, CLIP-ViT/L14 has a higher MRR score than the other two models. We also report the performance of the three CLIP models on FEATURE NORMS, CONCEPT PROPERTIES-test, and MEMORY COLORS in Table 9, indicating that the larger CLIP model has better performance across metrics.

C CEM Variations

C.1 Concreteness Prediction Model

In Table 11, we report the results obtained by the CEM model using predicted concreteness values (instead of gold standard ones). We predict these values by retraining the model of Charbonnier and Wartena (2019) using the concreteness scores of 40k words (all parts-of-speech) in the Brysbaert et al. (2014) dataset. We exclude 425 adjectives

that are found in the FEATURE NORMS, CONCEPT PROPERTIES, and MEMORY COLORS datasets.¹⁹ The concreteness prediction model uses FastText embeddings (Mikolov et al., 2018) enhanced with POS and suffix features. We evaluate the model on the 425 adjectives that were left out during training and for which we have ground truth scores. The Spearman correlation between them is 0.76, showing that our automatically predicted scores could be used in our ensemble model instead of the gold standard ones.

C.2 CEM Weight Selection

We also experiment with different ways of generating scores and combining the property ranks proposed by the models. (a) **CEM-pred**: We generate a concreteness score using the model of Charbonnier and Wartena (2019) and FastText embeddings (Babajewski et al., 2017). We train the model on the 40k concreteness dataset (Brysbaert et al., 2014), excluding the 425 adjectives found in our evaluation datasets. The model obtains a high Spearman ρ correlation of 0.76 against the ground truth scores of the adjectives in our test sets, showing that automatically predicted scores are a good alternative to manually defined ones. (b) **CEM-random**: We randomly generate a score for each property and

¹⁹In total, the three datasets contain 487 distinct properties (adjectives).

Model	Images	Non-Prototypical					Prototypical				
		Acc@5	Acc@10	R@5	R@10	MRR	Acc@5	Acc@10	R@5	R@10	MRR
RANDOM	✗	4.13	7.67	2.73	4.96	0.030	4.66	8.03	2.15	3.84	0.025
GLOVE	✗	22.59	33.20	16.99	26.76	0.124	30.05	44.56	15.68	26.71	0.124
GOOGLE-NGRAM	✗	45.19	57.96	39.22	58.80	0.240	39.64	56.99	24.06	36.47	0.142
BERT-LARGE	✗	35.76	51.28	30.22	48.12	0.197	45.60	58.81	28.16	39.42	0.191
ROBERTA-LARGE	✗	35.76	48.92	28.53	46.39	0.176	47.67	63.73	28.95	43.08	0.200
GPT2-LARGE	✗	36.35	48.92	29.92	45.79	0.181	40.93	55.96	24.12	37.23	0.166
GPT3-DAVINCI	✗	30.84	40.67	25.77	39.42	-	55.18	64.51	38.30	49.66	-
ViLT	✓	34.97	46.76	28.85	42.70	0.211	38.34	53.63	23.52	36.57	0.159
CLIP-ViT/L14	✓	32.22	43.81	25.08	37.95	0.159	52.59	69.95	33.67	49.82	0.226
CEM-GOLD (Ours)	✓	41.85	54.03	35.88	49.55	0.217	64.77	75.39	43.11	56.06	0.289
CEM-PRED (Ours)	✓	41.65	51.47	35.11	46.46	0.211	65.80	74.87	44.67	56.20	0.306

Table 10: Results obtained on the FEATURE NORMS dataset filtered by prototypical and non-prototypical properties. The splits are derived from (Apidianaki and Garí Soler, 2021).

	FEATURE NORMS				CONCEPT PROPERTIES-test				MEMORY COLORS		
	Acc@1	R@5	R@10	MRR	Acc@1	R@5	R@10	MRR	Acc@1	Acc@3	Acc@5
CEM-GOLD	40.1	<u>40.5</u>	53.3	.252	48.3	26.9	39.1	.171	<u>82.6</u>	96.3	99.1
CEM-PRED	<u>39.9</u>	40.4	52.5	<u>.251</u>	49.9	28.1	<u>40.0</u>	.175	84.4	97.2	99.1
CEM-RANDOM	35.4	38.3	51.0	.232	46.3	25.3	36.5	.162	62.4	90.8	94.5
CEM-AVERAGE	38.7	41.0	<u>53.0</u>	.249	48.3	<u>28.0</u>	40.2	<u>.173</u>	71.6	92.7	99.1
CEM-MAX	36.9	38.4	51.3	.238	<u>48.6</u>	26.7	38.1	.167	67.0	90.8	96.3
CEM-MIN	25.1	34.2	50.1	.204	30.1	21.2	34.1	.135	69.7	<u>95.4</u>	98.2

Table 11: Comparison of ensemble methods on the three datasets. The best-performed number of each column is **bolded** and the second-best is underlined.

use it to combine the ranks from two models. (c) **CEM-average**: We use the average of the property ranks; (d) **CEM-high**: We use the maximum rank of the property; (e) **CEM-low**: We use the minimum rank of the property. Table 11 shows the comparison between CEM and these alternative weight generation and ensembling methods on FEATURE NORMS. CEM achieves the highest performance across all metrics, indicating that concreteness offers a reliable criterion for model ensembling under unsupervised scenarios.

D Qualitative Analysis

D.1 Unigram Prediction Frequency

In Table 12, we report the mean Google unigram frequency (Brants and Franz, 2009) for all properties in the top 5 predictions of each model. We observe that our CEM model – which achieves the best performance among the tested models, as shown in Table 3 – makes predictions that involve medium-frequency words. This is a desirable property of our model compared to models which would instead predict highly frequent or rare words (highly specific or technical terms). This is the case for GPT3 and CLIP, which propose rarer attributes but obtain lower performance than CEM.

It is worth noting that, contrary to CLIP, GPT3 retrieves properties from an open vocabulary.

Given that Google NGrams frequencies are computed based on text, many common properties might not be reported. For example, FEATURE NORMS propose typical attributes of an “ambulance”: *loud*, *white*, *fast*, *red*, *large*, *orange*. The frequency of the corresponding property-noun bigrams (e.g., *loud ambulance*, *white ambulance*) are: 0, 687, 50, 193, 283, and 0. Meanwhile, the bigrams formed with less typical properties (e.g., *old*, *efficient*, *modern*, and *independent*) have higher frequency (1725, 294, 314, and 457). While language models rely on text and, thus, suffer from reporting bias, vision-based models can retrieve properties that are more rarely stated in the text.

D.2 Prototypical Property Retrieval

We carry out an additional experiment aimed at estimating the performance of the models on prototypical vs. non-prototypical properties. Prototypical are the properties which apply to most of the objects in the class denoted by the noun (e.g., *red strawberries*); in contrast, non-prototypical properties describe attributes of a smaller subset of the objects denoted by the noun (e.g., *delicious strawberry*). We make the assumption that prototypical

Model	CONCEPT PROPERTIES-test		FEATURE NORMS	
	Unigram Freq. ↓	Bigram Freq. ↓	Unigram Freq. ↓	Bigram Freq. ↓
BERT	53M	11.6K	55M	7.6K
ROBERTA	50M	6.8K	53M	6K
GPT-2	96M	10.3K	78M	6.4K
GPT-3	24M	6.5K	25M	2.8K
VILT	50M	6.2K	40M	3.8K
CLIP	11M	5.3K	18M	2.2K
CEM-GOLD	32M	7.4K	33M	4.1K
CEM-PRED	34M	7.1K	31M	6.1K

Table 12: Mean Google unigram frequency for the top-5 predictions by each model. We observe that CEM produces rarer words than most other models (excluding GPT3 and CLIP) while maintaining high performance.

properties are common and, often, visual or perceptual; we expect them to be more rarely stated in texts and, hence, harder to retrieve using language models than using images.

We use the split of the FEATURE NORMS dataset performed by [Apidianaki and Garí Soler \(2021\)](#) into prototypical and non-prototypical properties, based on the quantifier annotations found in the [Herbelot and Vecchi \(2015\)](#) dataset.²⁰ The first split Prototypical contains 785 prototypical adjective noun pairs (for 386 nouns) annotated with at least two ALL labels, or with a combination of ALL and MOST (*healthy banana* → [ALL-ALL-ALL]). The second set Non-Prototypical contains 807 adjective-noun pairs (for 509 nouns) with adjectives in the ground truth that are not included in the Prototypical set In Table 10, we report the performance of each model in retrieving these properties.

In the ALL, MOST column we consider properties that have at least 2 ALL annotations, with the combination of a MOST annotation, and in the SOME column, we consider all properties that do not contain NO and FEW annotations, and have at least one SOME annotation. The results confirm our intuition that non-prototypical properties are more frequently mentioned in text. This is reflected in the score of the NGram baseline for these properties. For prototypical properties, our CEM model outperforms all other models.

D.3 Multi-token Performance

Each model splits words into a different number of word pieces. Table 13 shows the number of multi-token properties for each model, and its per-

formance on these properties. We observe that all models perform worse than average (refer to Table 3 for the average performance) on the multi-token properties, however, CEM has the smallest reduction in performance compared to the average values, which could be because CEM relies on information from two models which have different tokenizers.

D.4 Qualitative Examples

Table 14 contains more examples of the top-3 predictions made by the models for nouns in the CONCEPT PROPERTIES-test and FEATURE NORMS datasets.

²⁰Three native English speakers were asked to rate properties in FEATURE NORMS based on how often they describe a noun, by choosing a label among [NO, FEW, SOME, MOST, ALL].

Model	# Multitokens	FEATURE NORMS				
		Acc@5	Acc@10	R@5	R@10	MRR
BERT-LARGE	106	0.0	0.0	0.0	0.0	0.009
ROBERTA-LARGE	590	23.77	32.02	22.64	32.27	0.182
GPT2-LARGE	12	0.0	0.0	0.0	0.0	0.018
GPT3-DAVINCI	0	-	-	-	-	-
ViLT	106	1.57	2.55	7.51	13.0	0.060
CLIP-ViT/L14	45	4.72	5.50	55.95	66.67	0.401
CEM-GOLD (OURS)	590/45	36.54 /1.2	43.81 /3.14	37.65 /13.10	49.59 /35.71	0.245 /0.124
CEM-PRED (OURS)	590/45	32.22/1.77	41.85/3.73	33.7/20.24	46.76/42.86	0.165/0.122
Model	# Multitokens	CONCEPT PROPERTIES-test				
		Acc@5	Acc@10	R@5	R@10	MRR
BERT-LARGE	429	0.0	0.33	0.0	0.59	0.006
ROBERTA-LARGE	1939	45.42	59.56	19.12	27.65	0.120
GPT2-LARGE	60	0.0	0.0	0.0	0.0	0.010
GPT3-DAVINCI	27	0.33	0.50	7.41	11.11	-
ViLT	429	1.66	3.99	2.43	5.77	0.029
CLIP-ViT/L14	300	16.47	20.13	39.12	49.12	0.029
CEM-GOLD (OURS)	1939/300	54.58/6.49	68.39/9.65	26.24/13.03	38.92/20.96	0.161/0.095
CEM-PRED (OURS)	1939/300	56.99 /5.63	69.87 /9.62	27.31 /12.12	39.35 /21.05	0.165 /0.078

Table 13: Performance on multi-token properties by each model. The best performance is highlighted in **boldface**. CEM uses two different tokenizers RoBERTa/CLIP. Hence, we report both results separated by a backslash (/).

Noun	Image	Model	Top-5 Properties
wand		RBTA	necessary,useful,unnecessary,white,small
		CLIP	magical,magic,cunning,fizzy,extendable
		GPT-3	long,thin,flexible,smooth,light
		CEM-GOLD	magical,long,brown,magic,adjustable
		CEM-PRED	magical,brown,magic,long,golden
horse		RBTA	healthy,white,black,stable,friendly
		CLIP	stable,majestic,fair,free,wild
		GPT-3	strong,fast,powerful,muscular,big
		CEM-GOLD	stable,friendly,free,wild,healthy
		CEM-PRED	stable,friendly,free,wild,healthy
raven		RBTA	black,white,harmless,aggressive,solitary
		CLIP	unlucky,nocturnal,dark,solitary,cunning
		GPT-3	black,glossy,sleek,shiny,intelligent
		CEM-GOLD	solitary,black,dark,harmless,rare
		CEM-PRED	solitary,black,dark,harmless,rare
surfboard		RBTA	expensive,white,comfortable,small,waterproof
		CLIP	paddled,overfished,aerodynamic,concave,beachwear
		GPT-3	hard,smooth,slick,colorful,long
		CEM-GOLD	waterproof,paddled,beachwear,long,cool
		CEM-PRED	waterproof,long,cheap,cool,durable
limousine		RBTA	expensive,black,white,empty,large
		CLIP	luxurious,decadent,ostentatious,expensive,showy
		GPT-3	long,sleek,spacious,luxurious,comfortable
		CEM-GOLD	expensive,luxurious,large,long,comfortable
		CEM-PRED	expensive,luxurious,large,long,comfortable
violin		RBTA	expensive,white,small,black,electric
		CLIP	acoustic,fiddly,strummed,traditional,rhythmic
		GPT-3	wooden,long,thin,stringed,musical
		CEM-GOLD	acoustic,fiddly,small,cheap,unique
		CEM-PRED	acoustic,small,unique,cheap,brown
barn		RBTA	large,white,small,red,common
		CLIP	old-fashioned,run-down,harvested,red,old
		GPT-3	old,large,red,wooden,rusty
		CEM-GOLD	red,large,old,spacious,portable
		CEM-PRED	red,old,spacious,large,rectangular
oak		RBTA	healthy,white,green,tall,harvested
		CLIP	green,sticky,edible,large,harvested
		GPT-3	strong,sturdy,hard,dense,heavy
		CEM-GOLD	green,harvested,large,edible,brown
		CEM-PRED	green,harvested,large,edible,brown
radish		RBTA	edible,poisonous,delicious,white,small
		CLIP	edible,nutritious,healthy,harvested,young
		GPT-3	crunchy,peppery,spicy,earthy,pungent
		CEM-GOLD	edible,healthy,harvested,delicious,white
		CEM-PRED	edible,white,harvested,healthy,delicious
toilet		RBTA	portable,dirty,open,common,small
		CLIP	sinkable,brown,emptied,round,short
		GPT-3	dirty,smelly,clogged,rusty,filthy
		CEM-GOLD	large,white,small,brown,sinkable
		CEM-PRED	portable,white,uncomfortable,waterproof,dirty
bluejay		RBTA	male,black,small,healthy,white
		CLIP	blue,gentle,crunchy,wild,friendly
		GPT-3	blue,small,blue,blue,blue
		CEM-GOLD	blue,friendly,edible,small,endangered
		CEM-PRED	blue,endangered,small,friendly,wild
donkey		RBTA	black,male,white,healthy,brown
		CLIP	humorous,annoying,short,brown,darned
		GPT-3	stubborn,strong,sure-footed,intelligent,social
		CEM-GOLD	brown,grey,large,short,slow
		CEM-PRED	brown,large,slow,hairy,friendly

Table 14: Random sample of Top 5 properties proposed by different models for nouns in the FEATURE NORMS and CONCEPT PROPERTIES-test dataset.