Representational Spaces of Color in Comparison

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Background: The nature of our semantic system and the extent to which concepts are grounded in our sensory-motor experience remain a matter of debate. In recent decades, distributional semantic models (DSMs) have provided a promising computational account of conceptual representations. Since DSMs derive the structure of lexical semantics from statistical regularities in large corpora of natural text, they have been criticized for neglecting embodied experience shaping human semantics (for an overview of the discussion, see [1]). Conversely, it has been argued that DSMs encode non-linguistic information implicitly, given that the function of language itself is to communicate about our sensory environment [1]. This is supported by previous work showing that distributional similarities converge with similarities encoded in the environment, such as geographical or temporal similarities [2, 3]. This raises the question of the extent to which DSMs capture representational structures experienced by our sensory-motor system.

The concept of color provides a particularly intriguing test case for this debate. Colors can be quantified in (at least) three representational domains: First, colors are a perceptual sensation caused by physical stimuli, which are more or less visually similar to one another. Second, the corresponding color words used to communicate about these colors are linguistic stimuli that occur in more or less similar linguistic contexts, which constitute the basis of semantic representations in DSMs. Third, humans have mental representations of color concepts, which can be assessed via behavioral tasks, such as similarity ratings. In our study, we investigate and compare color representations across these three distinct domains, to identify their representational alignment.

Methods and Preliminary Results: To this aim, the linguistic domain is operationalized using a distributional semantic model (FastText, [4]), while the visual domain is characterized through metrics of perceptual distance, namely CIEDE2000 and Euclidean distances within CIELAB space [5]. The resulting correlation between the linguistic (FastText, fig. 1) and visual (CIEDE2000, fig. 2) representational spaces of German color words was negligible ($r = .008$). Results were consistent for correlations between linguistic and Euclidean visual spaces and across other languages (English and Italian, rs ranged from -.094 to .042). These findings suggest that linguistic and visual color spaces differ substantially in their structures. For the third pillar of our comparative analyses, we are currently preparing data-collection to construct a mental semantic color space from human behavioral data, specifically similarity ratings. Data will be directly collected through a forced-choice paradigm and through psychological embeddings derived from a neural network model trained on the collected similarity ratings [6]. Stimuli include German color words and corresponding color images, enabling a differentiation between modalities of concept presentation.

Discussion: Preliminary results suggest that physical color distances do not predict how corresponding color words are used in language. Further analyses will allow us to assess whether behavioral distances align more closely with linguistic or physical distances of color representations and the interplay between these different representational spaces. Such comparisons will offer novel insight on how highly perceptual concepts such as colors are grounded in embodied experience.

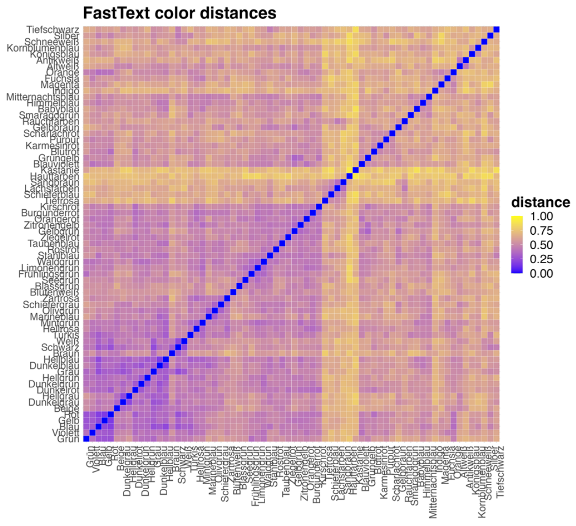

Figure 1: FastText linguistic color space.

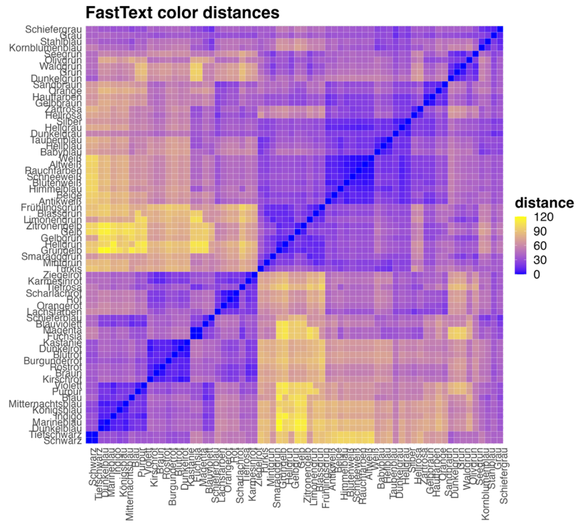

Figure 2: CIEDE2000 visual color space.

References

[1] Günther, F., Rinaldi, L., & Marelli, M. (2019). Vector-Space Models of Semantic Representation From a Cognitive Perspective: A Discussion of Common Misconceptions. *Perspectives on Psychological Science*, *14*(6), 1006–1033. https://doi.org/10.1177/1745691619861372

[2] Gatti, D., Marelli, M., Vecchi, T., & Rinaldi, L. (2022). Spatial representations without spatial computations.

[3] Louwerse, M., Raisig, S., Tillman, R., & Hutchinson, S. (2015). Time after time in words: Chronology through language statistics. Proceedings of the Annual Meeting of the Cognitive Science Society.

[4] Bojanowski, P., Grave, E., Joulin, A., & Mikolov, T. (2017). Enriching Word Vectors with Subword Information. *Transactions of the Association for Computational Linguistics*, *5*, 135–146. https://doi.org/10.1162/tacl_a_00051

[5] Luo, M., Cui, G., & Rigg, B. (2001). The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Research & Application*, *26*(5), 340–350. https://doi.org/10.1002/col.1049

[6] Roads, B., & Love, B. (2021). Enriching imagenet with human similarity judgments and psychological embeddings.