Preface

Vector embeddings of word meanings have become a mainstream tool in large scale natural language processing applications. The use of vectors to represent meanings in semantic spaces or feature spaces is also employed in cognitive science. Unrelated to natural language and cognitive science, vectors and vector spaces have been extensively used as models of physical theories and especially the theory of quantum mechanics. Crucial similarities between the vector representations of quantum mechanics and those of natural language are exhibited via bicompact linear logic and compact closed categorical structures in natural language.

The workshop series Semantic Spaces at the Intersection of NLP, Physics, and Cognitive Science (SEMSPACE) aims to exploit the common ground provided by vector spaces by bringing together researchers working at the intersection of NLP, cognitive science, and physics and offering them an appropriate forum for presenting their uniquely motivated work and ideas. Using the interplay between the three disciplines, the goal is to foster theoretically motivated approaches to understanding how meanings of words interact with each other in sentences and discourse via grammatical types, how they are determined by input from the world, and how word and sentence meanings interact logically.

The fourth SEMSPACE installment was held on the 6th-7th August 2020, in an online format. The June 2021 special issue of the Journal of Cognitive Science consisted of four selected and expanded papers based on SEMSPACE 2020 presentations. The present special issue adds two more (De las Cuevas et al, Duneau) complemented by two more recent solicited papers on the SEMSPACE themes (D. Wang et al, Wang-Mańcianica & Coecke).

The theoretical background for the papers by Duneau and Wang-Mańcianica & Coecke is the DisCoCat/DisCoCirc framework for compositional distributional semantics developed by Coecke and co-workers over the past decade. Duneau addresses a type of constraint satisfaction puzzle and shows how the meaning of such puzzles can be encoded in terms of the relations determined by the way the puzzle is formulated as a text built out of individual sentences. The key feature of the analysis is the *dynamics* of text interpretation that allows word meanings to

evolve as a text unfolds.

Whereas Duneau deals with the relations that make up a constraint satisfaction problem, Wang-Maścianica & Coecke focus on *spatial* relations and their composition. They present a model of spatial linguistic meaning with the property that the grammatical structure we use to describe space matches the compositional structure of the spatial content of language and show how this model naturally accommodates forms of reasoning that are dependent on the structure of physical space.

De las Cuevas et al also utilise the DisCoCat framework together with words represented as positive operators and completely positive maps. They design a series of compositional operators that combine words represented by positive operators into simple phrases and sentences, and further provide training techniques to allow composition operators to be learnt from data. The operators used are able to preserve hyponymy relations between words, so that this relationship can lift to an entailment relationship at the sentence level.

D. Wang et al address the ubiquitous problem of ambiguity in natural language as it manifests itself in ambiguous subject-verb and verb-object constructions where both the subject/object and the verb are ambiguous. Using methods and techniques from Quantum Information Theory, Contextuality-by-Default and degrees of contextual influences, they provide an explanation for findings of psycholinguistic research showing differences in the disambiguation of nouns versus verbs, and of cases of polysemy versus homonymy.

We thank the authors, participants and reviewers for the workshop, and hope that the papers collected here provide food for thought for the audience of the Journal of Cognitive Science.

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