AUTHOR(S) OF THE TARGET ARTICLE: Michael Gilead, Yaacov Trope, Nira Liberman

Word counts:
Abstract: 52
Main text: 917
References: 449
Entire text (total + addresses etc): 1549

Catching the intangible: a role for emotion?

Maria Montefinese
University of Padova
Via Venezia 12
35131 Padova
Italy
Tel: +39 (0)49 827 6149
Email: maria.montefinese@unipd.it
URL: https://sites.google.com/view/mariamontefinese

Ettore Ambrosini
University of Padova
Via Giustiniani 5
35128 Padova
Italy
Tel: +39 (0)49 821 4332
Email: ettore.ambrosini@unipd.it
URL: https://www.researchgate.net/profile/Ettore_Ambrosini

Antonino Visalli
University of Padova
Via Venezia 12
35131 Padova
Italy
Tel: +39 049 8277424
Email: antonino.visalli@unipd.it
URL: https://www.researchgate.net/profile/Antonino_Visalli

David Vinson
University College London
University College London
Gower Street
London WC1E 6BT
United Kingdom
Tel: +44 (0)20 7679 5311
Email: d.vinson@ucl.ac.uk
URL: https://www.ucl.ac.uk/pals/research/experimental-psychology/person/david-vinson/

ABSTRACT: A crucial aspect of Gilead and colleagues' ontology is the dichotomy between tangible and intangible representations, but the latter remain rather ill-defined. We propose a fundamental role for interoceptive experience and the statistical distribution of entities in language, especially for intangible representations, that we believe Gilead and colleagues' ontology needs to incorporate.

In the spirit of the predictive nature of cognition, we agree with Gilead and colleagues that a predictive brain framework for abstract representations, contemplated as a hierarchy ranging from the tangible to the intangible, could be salutary. However, it is important to recognize that although a crucial aspect of the ontology proposed by Gilead and colleagues is the dichotomy between tangible and intangible entities, the latter remain rather ill-defined despite the formal treatment (sect. 2.1, para. 3). I In particular, Gilead and colleagues define "intangible abstracta" (often called "abstract representations/concepts" in the literature on semantic representations) as categories whose concreta are not detected by our senses, but mainly transmitted from mind to mind using language. However, they also propose that some intangible dimensions of the intangible abstracta "may have an *innate* basis, or may be emergent properties discovered via *personal experience*" (sect. 2.1, para. 3)", properties also relevant for the modality-specific and multimodal abstracta (both based on sensorimotor features) (sect. 2.1, para.1-2). Consequently, the distinctions between the different kinds of representations are obscure and Gilead and colleagues' definition of "intangible abstracta" seems somewhat contradictory to us. Therefore, it is important to get a clear idea of how personal experience and social interaction combine to produce intangible abstracta.

In light of these theoretical considerations, we propose that many intangible representations could be intangible abstracta with affective content. The plausibility of this view has been supported by many studies demonstrating the crucial role of emotion for intangible abstracta (Crutch, Troche, Reilly & Ridgway, 2013; Kousta, Vigliocco, Vinson, Andrews & Del Campo, 2011). In particular, while tangible entities have direct sensory referents (Crutch & Warrington 2005; Montefinese, Ambrosini, Fairfield & Mammarella, 2013; Paivio, 1971), intangible abstracta tend to be more emotionally valenced (Crutch et al., 2013; Kousta et al. 2011; Vigliocco et al., 2013) and have low sensorimotor grounding (for a concise review, Montefinese, 2019). In line with the idea that affective content is particularly relevant for intangible abstracta representation, a number of neuroimaging studies showed that intangible abstracta processing increases activation in brain regions involved in emotion processing (Vigliocco et al., 2013; Wang et al., 2018), such as the rostral anterior cingulate cortex.

Very recently it has been proposed that *interoception* (the perception of the internal state of the body) contributes to the perceptual grounding of intangible abstracta. Crucially, interoception is the most important perceptual modality in the experience of emotions, especially the negative ones (e.g., fear and sadness), over and above the traditional five sensory modalities (Connell, Lynott & Banks, 2018). An exploration of emotion and of its perceptual grounding via interoception seems like a necessary step in building a comprehensive theory of abstract representational capacities.

Still, taking affective information into account might not suffice to capture representation of intangible abstracta. In this regard, recent multimodal models suggest that supplementing

affective information with information related to the statistical distribution of concepts in language (i.e., *distributional models* of semantic representation; Landauer & Dumais, 1997) drastically improves prediction of human affective judgments (Recchia & Louwerse, 2015; Bestgen & Vincze, 2012; Vankrunkelsven , Verheyen, Storms & De Deyne, 2018). More importantly, recent work by Lenci and colleagues (2018) reveals a strong link between distributional statistics and emotion: *intangible representations* have more affective content and tend to co-occur with contexts with higher emotive value (Lenci, Lebani and Passaro (2018). However, it is worth noting that the contribution of the distributional models to semantic representation goes beyond that of affective intangible abstracta. Indeed, it has been shown that these models can successfully account for semantic and linguistic judgments, as well as higher-level judgments such as probability judgments and risk perception in a human-like manner (Bathia, Richie & Zhou, 2019; Rotaru, Vigliocco & Frank, 2019). As is the case for emotion, the importance of distributional information for intangible abstracta is also supported by neuroimaging studies. Intangible abstracta reliably engage neural systems associated with linguistic processing (especially left anterior temporal cortex and left inferior frontal gyrus) to a greater extent than tangible abstracta (Wang et al., 2010). Increased activity for intangible abstracta in networks associated with language processing appears to be specifically associated with distributional similarity, vs. other aspects of intangible representations which do not appear to be localised to language-related networks (Wang et al., 2018). As intangible abstracta are mainly acquired through verbal experience (as Gilead and colleagues acknowledge in sect. 2.1, para. 3) and the distributional theory represents one of the main theoretical frameworks in semantic literature, it is surprising that such a role of language is not addressed directly. Given the importance of these models in explaining both intangible and tangible representations we think that Gilead and colleagues should incorporate them in their theory. Moreover, by revealing the statistical relations between abstract entities, distributional models represent a powerful tool to integrate Gilead and colleagues' account and predictive brain theories, which assume the brain as a statistical inferential machine.

In short, we believe that Gilead and colleagues have missed a chance to "provide cognitive scientists with an *accurate* ontology of the representational entities that exist in our mind—and that subserve predictive cognition" (sect. 5.1, para. 5). What we think is missing from their analysis is how emotion and distributional information fit in with the proposed ontology. In keeping with a metaphor used by the authors, interoceptive experience and linguistic distribution would represent two additional "tricks" used by our brain both to build the different layers of the representational hierarchy and to "transcend the here-and-now", and we think that the authors' model could benefit from integrating them.

Bhatia, S., Richie, R., & Zou, W. (2019). Distributed semantic representations for modeling human judgment. *Current Opinion in Behavioral Sciences*, *29*, 31-36.

Bestgen, Y., & Vincze, N. (2012). Checking and bootstrapping lexical norms by means of word similarity indexes. *Behavior Research Methods, 44,* 998–1006.

Connell, L., Lynott, D., & Banks, B. (2018). Interoception: the forgotten modality in perceptual grounding of abstract and concrete concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1752), 20170143.

Crutch, S. J., & Warrington, E. K. (2004). Abstract and concrete concepts have structurally different representational frameworks. *Brain*, *128*(3), 615-627.

Crutch, S. J., Troche, J., Reilly, J., & Ridgway, G. R. (2013). Abstract conceptual feature ratings: the role of emotion, magnitude, and other cognitive domains in the organization of abstract conceptual knowledge. *Frontiers in Human Neuroscience*, *7*, 186.

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14.

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review, 104,* 211–240.

Lenci, A., Lebani, G. E., & Passaro, L. C. (2018). The emotions of abstract words: A distributional semantic analysis. *Topics in cognitive science*, *10*(3), 550-572.

Montefinese, M. (2019). Semantic representation of abstract and concrete words: a minireview of neural evidence. *Journal of neurophysiology*, *121*(5), 1585-1587.

Montefinese, M., Ambrosini, E., Fairfield, B., & Mammarella, N. (2013). The "subjective" pupil old/new effect: is the truth plain to see?. *International Journal of Psychophysiology*, *89*(1), 48-56.

Paivio, A. (2013). Imagery and verbal processes. New York: Holt. Rinehart. & Winston, 1971.

Recchia, G., & Louwerse, M. M. (2015). Reproducing affective norms with lexical co-occurrence statistics: Predicting valence, arousal, and dominance. *The Quarterly Journal of Experimental Psychology, 68,* 1584–1598.

Rotaru, A. S., Vigliocco, G., & Frank, S. L. (2018). Modeling the Structure and Dynamics of Semantic Processing. *Cognitive science*, *42*(8), 2890-2917.

Vankrunkelsven, H., Verheyen, S., Storms, G., & De Deyne, S. (2018). Predicting Lexical Norms: A Comparison between a Word Association Model and Text-Based Word Co-occurrence Models. *Journal of Cognition*, *1*(1).

Vigliocco, G., Kousta, S. T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2013). The neural representation of abstract words: the role of emotion. *Cerebral Cortex*, *24*(7), 1767-1777.

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human brain mapping*, *31*(10), 1459-1468.

Wang, X., Wu, W., Ling, Z., Xu, Y., Fang, Y., Wang, X., … & Bi, Y. (2018). Organizational principles of abstract words in the human brain. *Cerebral Cortex*, *28*(12), 4305-4318.