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The TECo Database: Insights on The Semantic Organization of The Ecological Domain.

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Abstract

Contrasting the climate change emergency represents one of the major challenges of modern times. Knowing how people represent ecology-related phenomena is crucial to inform interventions aimed at promoting more effective pro-environmental behaviors. Despite this, literature on the topic is still scarce. To fill this gap, we asked 340 participants to rate 200 concepts—among which Ecological (N = 50, e.g., *deforestation*)—on numerous semantic dimensions (N = 39), drawing insights from the literature on conceptual organization. A Principal Component Analysis on our dataset revealed the presence of three major components explaining overall the variability of our set of concepts. Interestingly, Ecological concepts had a major role in all of them. Indeed, when compared to other conceptual categories—both related (i.e., Natural—e.g., *water*—and Geographical/Geopolitical—e.g., *ocean, city*) and not related (i.e., Technological—e.g., *Internet*) to the *green* domain—they figured among the most abstract (Component 1), impacting our political, social, and personal spheres (Component 2), scientific, emotionally charged, and evoking sensorimotor experiences (Component 3) concepts. Overall, our study has a threefold relevance. On a theoretical side, it can contribute to enriching theories on concepts by investigating a new semantic domain that jeopardizes the *concrete-abstract* dichotomy; on a scientific side, it might broaden categorization research by providing semantic norms for new conceptual domains (the TECo Database); on a societal side, it can enhance politics on these timely themes.

Keywords: Ecological concepts; rating task; Principal Component Analysis; conceptual organization; semantic norms.

Introduction

In contemporary times, the consequences of climate change are manifesting with growing force, generating significant apprehensions for the future (Hodgkinson & Innes, 2000).

Visible phenomena such as extreme weather events, drought or wildfires, biodiversity loss, melting glaciers, and rising sea levels are even more frequent, exerting a devastating impact on the health of both ecosystems (IPCC, 2007) and people (EPA, 2010; Patz et al., 2005). Human activities, such as the indiscriminate exploitation of the Earth's resources, often play a pivotal role in precipitating these occurrences. According to environmental psychologists, individuals know what the most appropriate towards-planet ways are to behave (McKenzie-Mohr, 2002; Vorkinn & Riese, 2001). Despite this, Earth's limits continue to be exceeded (e.g., see *Earth Overshoot Day* - NFBAs, 2023). One possible explanation for this incongruence may lie in a lack of understanding of how individuals represent reality. Indeed, actions are influenced also by cognitive representations (Myers, 2008). Therefore, the very first step to promote a transformative shift may be to understand how humans represent ecology-related phenomena. In simpler terms, what do words such as *climate change, sustainable development, pollution* (representing ecological phenomena), but also *fumes, pesticides,* and *industrial drain* (indicating causes of the ecological crisis) mean for them?

Although numerous studies have explored the emotional facets of the ecological crisis, such as eco-anxiety (Clayton, 2020; Pihkala, 2020), and identified factors driving pro-environmental behaviors (Li et al., 2019) and strategies to promote them (Schultz, 2014), there is a notable absence of research on how people represent Ecological concepts. Field literature has been until now limited to exploring cognitive representations of natural entities like animals or plants (e.g., Berlin, 2014) and geographical features (for a comprehensive review, see Falcinelli et al., 2024), neglecting ecology-related events.

Studies on conceptual organization can provide interesting insights into the representation of the ecological domain.

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Within this field, one important research line concerns the investigation of the differences in the acquisition, use, and processing of concepts with various levels of abstractness (Borghi et al., 2017; Brysbaert, Warriner & Kuperman, 2014). Compared to more Concrete concepts (e.g., *table*), more Abstract ones (e.g., *freedom*) generally do not refer to single, bounded, and perceptually identifiable objects (Borghi & Binkofski, 2014), but more often to complex situations with multiple entities in interaction (Barsalou & Wiemer-Hastings, 2005; Davis, Altmann & Yee, 2020). Due to their nature, they are usually thought to be more detached from sensorimotor experiences (Barsalou & Wiemer-Hastings, 2005), relying more on internal aspects (e.g., interoception - Connell, Lynott, & Banks, 2018) and on linguistic and social interactions (e.g., Borghi et al., 2018, 2019; Borghi, 2022; Fini et al., 2021).

This literature has been recently broadened by new proposals (i.e., Multiple Representations Views—e.g., Borghi et al., 2017; 2018; Borghi, 2023; Crutch et al., 2013; Dove, 2022; 2014; Zdrazilova, Sidhu & Pexman, 2018), which integrate classic perspectives by proposing to study the semantic characterization of concepts beyond the traditional *concrete-abstract* dichotomy. Indeed, concreteness~abstractness is just one of the many properties of concepts. Under these accounts, concepts are represented in a multidimensional semantic space encompassing multiple components, like sensorimotor, internal, linguistic, and social aspects, and all these factors differently contribute to their representation. For instance, Numerical concepts, despite being generally understood as Abstract, consistently elicit sensorimotor experiences (e.g., finger counting), as Concrete concepts typically do (Fischer & Shaki, 2018).

Despite the interesting insights, studies in this area typically restrict their investigation to properties traditionally studied in categorization research.

Starting from this theoretical background, our contribution aims to investigate for the first time in literature how a specific domain, *Ecology,* is conceptualized. To do so, we explored both typically investigated and new semantic properties by asking participants to rate concepts—among which Ecological ones—on numerous semantic dimensions. The choice of these dimensions was theoretically motivated: we selected aspects relevant for the spheres deemed more crucial by Multiple Representation Views, i.e. the sensorimotor, emotional, inner, linguistic, social, and political experiences. We then used a dimension reduction technique (i.e., a Principal Component Analysis - PCA) to identify dimensions accounting the most in explaining the variability of our dataset and to assess how they grouped together, and we finally compared Ecological concepts with other targeted categories—either related (i.e., Natural—e.g., *water*—and Geographical/Geopolitical—e.g., *ocean, city*) or not related (i.e., Technological—e.g., *Internet*) to the *green* domain—to explore how they organized in the PCA multidimensional semantic space. In the discussion, we will provide some theoretical reflections on how this newly emerging domain is characterized with respect to typical Abstract and Concrete concepts.

Method

Participants

Three hundred and forty participants (Females: 66%, $n = 225$, $M_{age} = 32.58$; $SD_{age} = 13.48$; Males: 33%, $n = 113$, $M_{age} = 38.67$; $SD_{age} = 17.07$; Intersex: 1%, $n = 2$, $M_{age} = 38.50$; $SD_{age} = 19.09$), aged more than 18 years old and all Italian native speakers, participated in the study. Participants were all Caucasian and resident in Italy (North: 29%, $n = 97$; Centre: 34%, $n = 117$; South: 37%, $n = 126$).

Sample size was calculated in line with previous works (e.g., Villani et al., 2019), enrolling at least 20 participants to gain evaluations on each semantic dimension (see Procedure section for more details).

Participants were contacted via an anonymous link either by spreading the surveys on social networks (e.g., Twitter, Instagram, Facebook) or through word of mouth/snowballing.

Materials

Words

The experimental wordset was composed of 200 Italian words, belonging to four categories: Ecological concepts ($n = 50$), Natural kind concepts ($n = 50$), “Geo” concepts ($n = 50$, i.e., $n = 25$ Geographical and $n = 25$ Geopolitical concepts), and Technological concepts ($n = 50$). Ecological, Natural and Geo concepts represented three conceptual categories related to *green*, but while Ecological concepts included words referring to ecology-related phenomena (e.g., *climate change, global warming*), or indicating causes of the ecological crisis (e.g., *pollution, intensive agriculture*), Natural concepts encompassed words referring to some consequences of climate change (e.g., atmospheric events such as *flood, blaze*) and to entities (e.g., animals and plants like *bee, tree*) typically affected by them, while Geo concepts included locations (both natural, e.g., *ocean, forest,* and urbanized, e.g., *city, region*) in which climate change phenomena usually occur. Finally, Technological concepts encompassed words not related to the *green* and concerning a phenomenon, i.e., the *technological progress*, which is currently as impacting as the ecological crisis (e.g., *computer, multimedia*).

Target words were extracted among the most frequently encountered in online glossaries belonging to official Italian websites pertinent to each topic. Glossaries were identified through a manual search on the Internet. For instance, Ecological words were selected from glossaries created by Italian institutions or associations involved in climate change awareness initiatives (e.g., https://www.isprambiente.gov.it/it/attivita/biodiversita/glossario). In addition, since Ecological concepts represented the category of our major interest, we made sure identified exemplars endorsed a high domain representativeness. To do so, we asked an independent sample of 20 Italian young adults (Females: 80%, $n = 16$, $M_{age} = 36.69$; $SD_{age} = 10.28$; Males: 20%, n = 4, $M_{age} = 36.50$; $SD_{age} = 12.92$) to rate our 50 Ecological concepts on their level of domain representativeness with a 7-point Likert scale (from 1 = "*very few*" to 7 = "*very much*"). We found that the word subset was overall highly representative of the Ecological domain ($Mdn = 5$; $M = 5.07$; $SD = 1.80$; $SE = 0.06$).

Dimensions

The whole wordset was rated by participants on 39 semantic dimensions. They included typically investigated conceptual properties in literature, features of recent interest in the field, or completely new aspects. Below we report a description of just those discussed in this paper. Details on all the others—along with the instructions for dimensions—can be found in the OSF repository (https://doi.org/10.17605/OSF.IO/M6PH9).

Among the most traditional dimensions, we first included some typically used to discriminate between Abstract and Concrete concepts, i.e., Imageability (Paivio, Clark, & Khan, 1988; Paivio, 1990) and Context Availability (Schwanenflugel, Akin, & Luh, 1992), relating to the easiness by which a concept evokes mental images and different contexts, respectively; and Frequency, indicating the frequency of occurrence of a word in written and spoken language (Laudanna & Burani, 1995).

Second, in line with Multiple Representation Views, we inserted semantic properties testing to what extent concepts ground in different kinds of experiences. Specifically, we targeted sensorimotor experiences with Perceptual Strength, indicating the degree by which a concept can be experienced through the five sensory modalities (i.e., through hearing, smell, taste, touch, and vision - Connell & Lynott, 2012; 2014; Lynott & Connell, 2013); and Action Effectors, investigating how much a concept activates bodily parts like hands/arms, feet/legs, mouth/throat, and torso (Lynott et al., 2019). We tested social experiences with Social Metacognition, referring to the amount of need for others' help to understand the meaning of a concept (Borghi et al., 2018; 2019); and Social Valence, indicating how much a concept is socially relevant (Villani et al., 2019). We also targeted internal components with Metacognition, indicating how much a word activates mental processes (Villani et al., 2019). Other two dimensions we considered were related to word acquisition, i.e., Age of Acquisition (Gilhooly & Logie, 1980) and Modality of Acquisition (Wauters et al., 2003), which refer to the age and experiential modality (sensorimotor~linguistic) through which a concept is tough to be acquired, respectively. Finally, we also included dimensions related to emotional aspects, like Emotionality, indicating the amount of emotional charge of a concept (Ponari, Norbury & Vigliocco, 2018; Vigliocco et al., 2014).

Among the recent or novel semantic dimensions, we included some referring to metacognitive processes, i.e., Word Confidence and Confidence in Experts (Mazzuca et al., 2022), indicating how confidently individuals think they or field experts, respectively, master the meaning of a word; one dimension concerning the Easiness of Providing a Definition of a word; and a last one indicating the perceived amount of scientificity of a concept (Scientificity).

Innovatively, some dimensions concerned the impact of concepts in our life, such as Political Relevance, indicating how much a concept is politically salient, i.e., it can generate social debates (taking inspiration from Mazzuca & Santarelli, 2022); Perceived Impact of the concept in our past, present, and future life; and the perceived amount of Personal Experience individuals can do with its referents. Finally, a last dimension, called Naturalness~Artificiality, investigated where referents of concepts are perceived to lie in the *natural~artifactual* continuum (taking insights from Forde & Humphreys, 2005).

Procedure

The study was approved by the Ethics Committee of the Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome (Prot. n. 000147 - 04/02/2022). Participants took part in an online survey implemented on Qualtrics Platform. After providing consent to participate in the study, they were asked to perform a rating task, evaluating words on target semantic dimensions using 7-point Likert scales. In the last section of the survey, participants provided their socio-demographic information (e.g., age, sex, educational level). The survey ended with a brief debriefing about the study's purposes. Participants spent on average one hour of time, and they were allowed to take a break at any time during the execution.

We implemented a total of 17 surveys, each of which included the entire set of words ($N = 200$) to be rated on two or more semantic dimensions (in line with Villani et al., 2019). Surveys ($n = 3$) encompassed more than two semantic properties when these represent sub-categories of the same dimension (e.g., past, present, and future for "Perceived Impact" dimension). Each survey was compiled by an independent sample of 20 participants, and each person filled only one survey. In line with this, we gained evaluations from 20 participants per word per dimension.

Data Analysis

Data was pre-processed and analyzed through RStudio (version 4.2.2 - R-Core Team, 2023). "Tidyverse" R's package (Wickham et al., 2019) was used to prepare dataset(s) for analyses.

As a first step, we calculated the interrater reliability of our data (i.e., Cronbach's alpha - Cronbach, 1951), a measure of the internal consistency of the ratings provided by each pool of 20 participants per dimension. The Cronbach's alphas appeared excellent for all of them, ranging from .90 to 1.00.

Then, we extracted the mean score and standard deviation per word per dimension. This allowed us to create the TECo Database, containing semantic norms for Ecological along with Geo, Natural, and Technological concepts. The database is publicly available at the OSF repository (https://doi.org/10.17605/OSF.IO/M6PH9).

To explore the semantic organization of concepts, we performed a Principal Component Analysis (Jolliffe, 2010) using "tidymodels" R's package (Kuhn & Wickham, 2020). PCA is a multivariate analysis technique useful to extract the most relevant dimensions explaining the variance of a wordset, also allowing to investigate how they group together (in Components). Before applying PCA, all the variables (i.e., mean scores per word per dimension) were centered and standardized. In the PCA, we entered the Category of Word (Ecological, Geo, Natural, Technological) and Target Word (i.e., our 200 words) as outcome variables and the 39 dimensions as numerical predictors. In line with this, 39 components were extracted.

To assess differences across categories of concepts on each dimension encompassed by the identified PCA components, a mixed Ordinal Regression Model was fitted using "ordinal" R's package (Christensen, 2022). The model (from now, "Model") featured rating scores as dependent variables, the interaction between Category of Word (Ecological, Natural, Geo, Technological) and Dimensions (N = 23) as a fixed factor, and Target Words and Participants as random intercepts. The significance of the interaction was assessed with a Type III ANOVA using "RVAideMemoire" R's package (Hervé, 2022), and pairwise comparisons across categories of concepts on each dimension were fitted using "emmeans" R's package (Lenth et al., 2023), with adjusted p-values using Tukey's corrections.

Results

Exploring Components and Dimensions Accounting The Most in Explaining The Wordset Variability.

Among the 39 components extracted by the PCA, we focused only on the first three, since all the others contributed to explain the variability of data less than 5%, each. The three identified components described overall 65% of the dataset variance, with Component 1 (PC1) explaining 33%, Component 2 (PC2) 18%, and Component 3 (PC3) 14% of variance.

We then explored the dimensions that contribute the most to each component. Specifically, we extracted dimensions whose weight (W) was higher than |.2|—usually interpreted as a small effect size (Cohen, 1988). This resulted in six dimensions for PC1, nine dimensions for PC2, and in eight dimensions for PC3 (see Figure 1).

Figure 1: Contribution of dimensions weighting more than |.2| on PC1, PC2, and PC3, along with their values.

Looking at the contribution of dimensions to each component, PC1 seemed to reflect the general distinction between Abstract and Concrete concepts, with a side (right) pointing to more Concrete words—i.e., concepts for which is easier to think about a context associated with (W: .24), highly imaginable (W: .24), and easier to be defined (W: .24)—and another (left) pointing to more Abstract words—i.e., concepts for the understanding of which we need more the others' help (W: -.26), that are acquired later (W: -.25) and principally through linguistic experiences (W: -.24).

The second component (PC2) was instead characterized by dimensions linked to social, political, and personal spheres. Specifically, it mainly encompassed words indicating entities perceived as socially (W: .33) and politically (W: .26) relevant, having a high impact on our future (W: .34), present (W: .33), and past life (W: .23), frequently encountered in written and spoken language (W: .29), which are personally experienced (W: .26), the meaning of which is well mastered (W: .26), and activating mental processes (W: .21).

Finally, the third component (PC3) was mainly characterized by an opposition between words referring to entities that are perceived as well mastered by field experts (W: -.23) and artifactual (W: -.22) (left side), against concepts conceived as emotionally charged (W: .33), indicating things experienced through torso (W: .33), mouth/throat (W: .33), feet/legs bodily parts (W: .29), and through olfactory sensory modality (W: .26), and considered scientific (W: .21) (right side).

Exploring The Distribution of (Ecological) Concepts in The Multidimensional Semantic Space.

Once the most relevant components of the PCA were identified, we visually inspected how Ecological concepts fitted in the multidimensional semantic space resulting from the PCA, also contrasting them with all the others targeted categories (see Figure 2). We validated our visual inspection through results from the Model, which yielded a significant interaction between the variables, $\chi_2(66) = 15533.2$, $p < .01$.

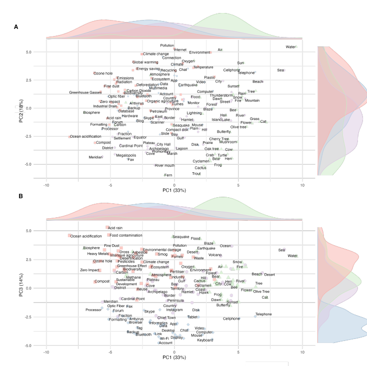

Figure 2: Panel A) Distribution of Target Words in the bidimensional space resulting from the interception of PC1

and PC2 (Panel A) and of PC1 and PC3 (Panel B), along with their distinction into categories (Ecological, Geo, Natural, and Technological).

By looking at Figure 2, Panel A, we firstly find that Ecological concepts characterize mostly as abstract. Indeed, in line with the characterization of our PC1 which opposes words endorsing properties of typical Abstract concepts on the left with more Concrete words on the right, we see that Ecological concepts (e.g., *ocean acidification, ozone hole, compost*) principally lie in the leftmost part of the plot, along with Technological concepts (e.g., *processor, optic fiber, formatting*), and they oppose mainly Natural concepts (e.g., *water, cat, grass*). Coherently with that, participants rated Ecological concepts as the words for which they felt the need for others' help to understand their meaning highest (Ecological *vs* Technological, $z = 7.97$, SE = .10, $p < .0001$; Ecological *vs* Natural, $z = 18.19$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 13.42$, SE = .10, $p < .0001$), and as the most linguistically (Ecological *vs* Technological, $z = 4.33$, SE = .10, $p = .0001$; Ecological *vs* Natural, $z = 10.36$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 5.05$, SE = .10, $p < .0001$), and the latest acquired concepts (together with Technological concepts, Ecological *vs* Technological, $z = 2.46$, SE = .10, $p = .0666$; Ecological *vs* Natural, $z = 22.07$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 11.50$, SE = .10, $p < .0001$). In line with this abstract characterization, participants perceived Ecological concepts as evoking fewer contexts than all the other categories (Ecological *vs* Technological, $z = -3.37$, SE = .10, $p < 0.01$; Ecological *vs* Natural, $z = -11.01$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = -8.42$, SE = .10, $p < .0001$), the hardest to be defined (Ecological *vs* Technological, $z = -7.44$, SE = .10, $p < 0.0001$; Ecological *vs* Natural, $z = -13.61$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = -7.95$, SE = .10, $p < .0001$), and among the least imaginable concepts (together with Technological ones, Ecological *vs* Technological, $z = -1.70$, SE = .10, $p = .32$; Ecological *vs* Natural, $z = -10.90$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = -7.23$, SE = .10, $p < .0001$).

Another interesting aspect of Ecological concepts is that they picture among the most influential words for both personal and public spheres. Indeed, by looking at Figure 2, Panel A, we can find them (e.g., *pollution, environment, climate change*) predominant in the uppermost part of the plot—i.e., where the positive loadings of our PC2 fall—again together with Technological concepts (e.g., *Internet, connection, chat*). Coherently with that, participants rated Ecological concepts as the most socially (Ecological *vs* Technological, $z = 4.37$, SE = .10, $p = .0001$; Ecological *vs* Natural, $z = 14.51$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 10.30$, SE = .10, $p < .0001$) and politically relevant concepts (Ecological *vs* Technological, $z = 23.08$, SE = .10, $p < .0001$; Ecological *vs* Natural, $z = 26.66$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 24.27$, SE = .10, $p < .0001$) and the ones with the highest impact on our future (Ecological *vs* Technological, $z = 4.10$, SE = .10, $p = .0002$; Ecological *vs* Natural, $z = 6.80$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = 9.81$, SE = .10, $p < .0001$) and present lives (together with Technological ones, Ecological *vs* Technological, $z = -1.14$, SE = .10, $p = .67$; Ecological *vs* Natural, $z = 2.88$, SE = .10, $p = .02$; Ecological *vs* Geo, $z = 5.62$, SE = .10, $p < .0001$), although conceived with an impact in our past life lower than other semantic domains (similarly to Geo concepts, Ecological *vs* Geo, $z = -1.07$, SE = .10, $p = .71$; Ecological *vs* Technological, $z = -6.92$, SE = .10, $p < .0001$; Ecological *vs* Natural, $z = -3.15$, SE = .10, $p = .01$). In addition, individuals considered them among the most frequently encountered concepts (together with Technological ones, Ecological *vs* Technological, $z = 0.46$, SE = .09, $p = .97$; Ecological *vs* Natural, $z = 2.85$, SE = .09, $p = .02$; Ecological *vs* Geo, $z = 2.62$, SE = .09, $p = .04$), and among those activating mental processes the most (together with Natural and Geo concepts, Ecological *vs* Natural, $z = 0.41$, SE = .10, $p = .98$; Ecological *vs* Geo, $z = 1.43$, SE = .10, $p = .48$; Ecological *vs* Technological, $z = 3.48$, SE = .10, $p = .001$). Ecological concepts were evaluated also as the least experienceable (similarly to Geo concepts, Ecological *vs* Geo, $z = -0.95$, SE = .10, $p = .78$; Ecological *vs* Technological, $z = -10.99$, SE = .10, $p < .0001$; Ecological *vs* Natural, $z = -3.31$, SE = .10, $p = .01$) and the least mastered concepts (similarly to Geo and Natural concepts, Ecological *vs* Geo, $z = -1.31$, SE = .10, $p = .56$; Ecological *vs* Natural, $z = -2.42$, SE = .10, $p = .07$; Ecological *vs* Technological, $z = -7.40$, SE = .10, $p < .0001$).

Finally, Ecological concepts appeared as concepts highly scientific, emotionally charged, and activating sensorimotor experiences. Indeed, by looking at Figure 2, Panel B, we can find them (e.g., *acid rain, food contamination, ocean acidification*) predominant in the uppermost part of the plot—corresponding to the right side of our PC3—, along with some Natural (e.g., *seaquake, flood, blaze*) and Geo concepts (in particular, Geographical, e.g., *ocean, sea, desert*). They contraposed in the lowermost part of the graph mostly to Technological concepts (e.g., *account, keyboard, Wi-Fi*), which refer to entities well mastered by field experts and artificial—in line with the characterization of the left side of our PC3. Coherently with this visual inspection, participants rated Ecological concepts as the most scientific words (Ecological *vs* Technological, $z = 3.35$, SE = .094, $p < .01$; Ecological *vs* Natural, $z = 2.97$, SE = .09, $p = .016$; Ecological *vs* Geo, $z = 3.80$, SE = .094, $p < .001$), the most emotionally loaded (similarly to Natural ones, Ecological *vs* Natural, $z = -1.47$, SE = .10, $p = .45$; Ecological *vs* Technological, $z = 25.21$, SE = .11, $p < .0001$; Ecological *vs* Geo, $z = 9.71$, SE = .10, $p < .0001$), and among those activating sensorimotor experiences of different kinds the most. Specifically, they appeared among the most activating mouth/throat effectors (Ecological *vs* Technological, $z = 18.95$, SE = .11, $p < .0001$; Ecological *vs* Natural, $z = 2.80$, SE = .10, $p = .03$; Ecological *vs* Geo, $z = 8.95$, SE = .10, $p < .0001$), the torso bodily part (together with Natural concepts, Ecological *vs* Natural, $z = -0.36$, SE = .11, $p = .98$; Ecological *vs* Technological, $z = 15.53$, SE = .11, $p < .0001$; Ecological *vs* Geo, $z = 3.71$, SE = .11, $p = .001$), the feet/legs effectors (specifically, more than Technological concepts, $z = 16.81$, SE = .11, $p < .0001$, but less than Natural, $z = -2.68$, SE = .1028, $p = .04$, and Geo concepts, $z = -7.155$, SE = .10, $p < .0001$), and the smell sensory modality (specifically, more than Technological, $z = 26.05$, SE = .16, $p < .0001$, and Geo concepts, $z = 5.42$, SE = .11, $p < .0001$, but less than Natural concepts, $z = -5.06$, SE = .11, $p < .0001$). These sensorimotor activations might be due to the actions of smell, eating, breathing or, overall, speaking about, these concepts elicit (e.g., *pollution, fine dust, food contamination*), as well as to limbs movements such ecology-related concepts evoke (e.g., *blaze, earthquake, flood*). Finally, participants rated Ecological concepts as the least mastered by field experts (Ecological *vs* Technological, $z = -8.93$, SE = .10, p < .0001; Ecological *vs* Natural, $z = -6.66$, SE = .10, $p < .0001$; Ecological *vs* Geo, $z = -2.83$, SE = .10, $p = .02$), and as less artificial than Technological concepts ($z = -24.95$, SE = .126, $p < .0001$) but more than Natural and Geo concepts (Ecological *vs* Natural, $z = 38.86$, SE = .12, $p < .0001$; Ecological *vs* Geo, $z = 15.37$, SE = .11, $p < .0001$).

Discussion and Conclusion

Overall, our results provide insights into the conceptual representation of the ecological domain. We asked participants to evaluate concepts—among which Ecological ones—according to several semantic properties, and then by using a PCA we extracted and inspected the most important dimensions accounting for the wordset variability.

Firstly, we found that Ecological concepts characterized mostly as Abstract concepts (PC1). Indeed, similarly to them and more than other conceptual domains (e.g., Natural and Geo), they were later (Gilhooly & Logie, 1980) and more linguistically (Wauters et al., 2003) acquired, harder to define, less imaginable (Paivio, 1990), evoking less contexts (Schwanenflugel et al., 1992), and people believed they needed the help of others more to understand them (e.g., Borghi, 2022).

Second, Ecological concepts were among the most impacting words on personal and public spheres (PC2). Indeed, they figured as the most politically and socially relevant concepts, the ones with the highest impact on our life (especially present and future), and among the most frequently heard and mental processes-activating concepts, despite being less experienceable and mastered than concepts from other semantic domains (such as the Technological one). From a theoretical perspective, also in this case Ecological concepts had a more Abstract-like characterization. Indeed, most of the dimensions encompassed by our PC2 and concerning Ecological concepts represent typical properties related to abstractness (e.g., high political and social value - Mazzuca & Santarelli, 2022; Villani et al., 2019; low word confidence - Mazzuca et al., 2022; high mental processes involvement - Villani et al., 2019).

Interestingly, in the last component (PC3) Ecological concepts also displayed some "concrete" features. Indeed, despite being perceived as highly emotionally charged and scarcely mastered by field experts as usually Abstract concepts are (Mazzuca et al., 2023; Ponari et al., 2018), they also appeared as words highly activating sensorimotor experiences (e.g., mouth/throat and torso bodily parts, smell sensory modality, and feet/legs effectors—to a minor extent), like typical Concrete concepts (Barsalou & Wiemer-Hastings, 2005).

So, more than for other semantic domains (like Natural, Geo, and Technological) the characterization of Ecological concepts results to be mixed—*hybrid*—between Abstract and Concrete concepts, even if mostly shifted towards the abstract polarity. Furthermore, Ecological concepts display interesting characteristics concerning dimensions not usually investigated in categorization research (e.g., high life-impact, high amount of scientificity).

In line with this, from a theoretical perspective, our results highlight the necessity to integrate classic perspectives on concepts with new insights from recent theories, but also to go beyond them. Indeed, investigating Ecological concepts just by forcing them into the rigid *concrete-abstract* dichotomy might have obscured their potentially *hybrid* nature; at the same time, relying only on traditionally investigated properties to characterize them might have caused valuable information about their multivarious character to be lost. More generally, our results highlight the limitation of the *concrete-abstract* dichotomy, showing that there are concepts, like the Ecological ones, that have concrete referents, but that people consider more Abstract than Concrete, and reveal that abstractness is a multidimensional and flexible construct.

From a scientific perspective, the TECo Database resulting from our investigation might contribute to enhancing research on this new emerging and increasingly urgent topic, by providing numerous semantic norms that can be used to select linguistic stimuli for future studies.

Finally, on a societal side, giving first insights into how people represent ecological issues is undoubtedly useful to implement more efficient awareness campaigns to cope with the climate change emergency. The abstract characterization of Ecological concepts might be one of the causes why, even if laypeople appear sensitive to ecological problems, this sensitivity often does not lead to pro-environmental actions. To illustrate, our data show that Ecological concepts are hard to imagine and weakly linked to contexts, as typically Abstract concepts are. So, it might be hard to reduce *resource waste* if one feels difficulties linking it to various practical actions such as *closing the water while shampooing* or *turning off lights when they are not necessary*. By being aware of this, stakeholders might invest more resources in practical interventions aimed at reducing these *Ecology*'s abstract features (e.g., by providing more practical examples in advertising), thus supporting Earth wellness.

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