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INTRODUCTION

An Introduction to the Cognitive Neuroscience of Language Embodiment and Relativity Special Issue of the *Language Learning* Cognitive Neuroscience Series

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Embodied cognition is a theory rooted in biology that posits human cognition as originating from direct sensorimotor experience of the world (Barsalou, 1999, 2008; Lakoff & Johnson, 1980; Varela et al., 1991). Linguistic relativity is a theory inspired by unfinished work by Benjamin Lee Whorf (1956) and his mentor, the eminent linguist Edward Sapir. It postulates that language forms can and do constrain, or "shape," human perception and conceptualization of the world (Levinson & Wilkins, 2006). The two theories are evidently linked. Whereas language embodiment, a significant subcomponent of embodied cognition, conceptualizes language as grounded in sensorimotor interactions with the environment, linguistic relativity hypothesizes the reverse: Language representations can influence people's sensorimotor interactions with the world.

Even though they make intuitive sense to some (us, for instance), both these theories have faced strong objections from prominent scholars. Fodor (1983), for instance, strongly advocated for a computational conception of mind as a collection of functional modules that can operate independently from one

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another. He thus argued that cognitive processes are largely independent of the body's interactions with the environment, and that perceptual processes are highly encapsulated and their function is largely unaffected by top-down processes. Pylyshyn (1986) formulated strong objections against a sensorimotor approach to human cognition, which in his view must be built from abstract, symbolic processing based on computations estranged from the physical body (see also Firestone & Scholl, 2016). In the same vein, although less confrontational as regards embodiment, Pinker (1997, 2002) has emphasized innateness and abstract reasoning as a key aspect of cognition. He has shown some degree of hostility towards linguistic relativity, however, which he has called trivial and absurd (Pinker, 1997).

Whereas some scholars consider linguistic relativity naive (e.g., Pinker, 1994), others have gone as far as to suggest that embracing relativity is dangerous (e.g., McWhorter, 2014). The expression of strong opinions in the sciences and humanities is generally a good thing, provided the debate remains courteous, constructive, and based on evidence rather than personal opinions devoid of an empirical basis. To this day, however, evidence testing the validity of language embodiment and relativity is lacking. Although a plethora of studies and opinion pieces have argued for or against these theories, the arguments presented overall lack grounding in experimental measures and observations that distance themselves from subjective evaluation.

At this juncture, we would like to highlight an important point: It is not only conceptual papers that have argued such theories to be weak and inconsequential that suffer from a lack of rigorous, objective scientific evidence, but also numerous empirical studies that have explored correlates of language embodiment and linguistic relativity on the basis of introspection or overt reports. Studies using questionnaires and structured interviews with speakers of different languages and bilinguals (e.g., Dewaele, 2010; Pavlenko, 2003) often require individuals to give an account of their subjective experiences of how language shapes their perception, reasoning, affect, or decision making. Although these can be useful gauges of people's understanding of lived experiences, the instruments used, and the data collected, are entirely language-based and metacognitive in nature. An idiosyncratic approach of this kind to language grounding and relativity effects means that no generalizable claim can be made about the patterns observed. One can argue that such studies showcase effects of language on language. They do not, therefore, provide much information about human cognition, or perception, or conceptualization outside language, and thus do not contribute directly to prevailing theories dealing with the effects of linguistic form on cognition.

If one asks a native speaker of Greek whether they see light and dark shades of blue as two different colors, especially through the medium of Greek, they could well say that "naturally, they are different colors." Whether or not this relates to the fact that Greek has two color terms, *ghalazio* and *ble*, to label the two shades of blue, and whether or not the answer depends on their knowledge of a second language that does not make this distinction (e.g., French or German), one cannot conclude that they actually *perceive* these two shades of blue as different. To draw any inference in the domain of perception, one needs to measure correlates of perception, for instance by using a color discrimination task, preferably in conditions where language is minimally involved or even actively inhibited (e.g., Sinkeviciute et al., 2024).

Studies relying solely on metacognitive evaluations and overt reports from participants can be misleading, because conclusions often have no common basis for interpretation and are confounded by the authors' own intuitions. Arguably, most language effects on cognition, if they exist, happen outside conscious awareness. In order to obtain support for (or challenge) the theories and gain new insights, researchers must thus turn to methods that go beyond the description of overt manifestations of language knowledge and "surface" indicators of performance (i.e., external manifestations of comprehension and production). The field needs paradigms that orient the participants' attention towards nonverbal perceptions and conceptualizations that are predicted to be mediated by language. Even more needed are measurements that are not open to subjective or metacognitive evaluation, such as those derived from neuroscientific methods, like electroencephalography and neuroimaging. This may in part explain why cognitive neuroscience methods have seen such a spectacular expansion over the past three decades, involving increasingly sophisticated methods and interdisciplinary approaches.

This special issue on the cognitive neuroscience of language embodiment and relativity (CoNSoLER) covers a range of key topics in the study of embodied cognition and linguistic relativity. The collection of contributions encompasses a diverse array of questions, methodologies, approaches, and analytical frameworks. All nine papers are empirical contributions reporting results of experiments conducted with monolingual and/or bilingual participants, or simulation data in the case of Dobler et al. (2024). The linguistic spectrum spans several natural languages: Mandarin Chinese, English, German, Lithuanian, Norwegian, and Spanish. The research focuses on different levels of language representation, from grammatical markers to sentences, via words. A variety of stimuli, including color patches, olfactory food samples, visual objects, spoken language, text, complex sentences, animated sequences, and video clips,

allow exploration of categorical perception effects, concrete and abstract concept learning, metaphor processing, and time conceptualization. The investigations are founded on a variety of methodological practices, ranging from psycholinguistic behavior measurements to modeling, via reaction time modeling and event-related potentials.

Critically, in all the studies reported in this special issue, the authors distanced themselves from the language representations or language mechanisms hypothetically driving the phenomenon being measured, by using tasks in which language has minimal involvement or relevance: smell/taste categorization (Bylund et al., 2024), color discrimination (Sinkeviciute et al., 2024), time conceptualization (Athanasopoulos & Su, 2024), and temporal transition estimation (Vanek & Zhang, 2024). Another set of studies not only used tasks keeping language involvement peripheral, but also collected implicit measures of unconscious processing directly derived from brain activity that are not susceptible to subjective modulation or strategic influence: object categorization (Casaponsa et al., 2024), object category learning (Maier & Abdel Rahman, 2024), embodiment of perceived power (Wei et al., 2024), and motion transitivity (Xue & Williams, 2024). Finally, and perhaps achieving the greatest level of detachment possible from language representations, the study by Dobler et al. (2024) offers insights into how abstract concepts can be grounded in a biologically constrained model of semantic memory.

To assist your exploration of the CoNSoLER special issue and help you to pinpoint contributions of specific interest, we have assembled Table 1. This table is designed not only to represent the different approaches and methodologies implemented in the studies reported in the issue but also to underscore the commonalities that thread through the nine papers.

The range of questions and approaches presented offers opportunities for knowledge transfer across research domains and opens the way for new cross-disciplinary ventures. Interdisciplinary science does not happen just because like-minded academics are invited to exchange ideas at a special event such as a conference. A process of mutual discovery and adaptation is needed, which entails that scholars consider not only approaches slightly different from their own, but also what other researchers in the field consider to be the fundamental questions that need answering, as well as the methods that can deliver such insights. Towards the end of this introduction, we consider how the different approaches presented in this special issue offer promising novel research endeavors and new cross-fertilization opportunities going forward.

Table 1 Synopsis of the parameters, variables, and characteristics of the papers, in the order in which they appear in this issue of the *Language Learning* Cognitive Neuroscience Series

Paper	Status	Language(s)	Method(s)	Materials	Procedure(s)	Modality	Measures	Targeted process(es)
Bylund et al.	Native speakers & bilinguals	Norwegian–English & English	Behavioral	Tasting samples	Similarity & intensity judgments	Gustatory & visual	Ratings	Taste & language category labels
Sinkeviciute et al.	Bilinguals & multilinguals	Lithuanian, Norwegian	Behavioral	Color patches, digits	Color discrimination, verbal interference, similarity judgment	Visual	Ratings, RTs	Color discrimination & color category labels
Athanasopoulos & Su	Late bilinguals	Chinese–English	Behavioral	Sentences, diagram	Temporal diagram task, temporal focus questionnaire	Reading & visual	Location coding, ratings	COVID-19 quarantine & representation of time along front–back axis
Vanek & Zhang	Native speakers & second language learners	English, Mandarin Chinese	Behavioral	Spoken sentences, video clip	Event boundary marking, event segmentation	Motor: visual slider adjustment	Start point & end point bias, event duration	Time & temporal transitions
Casaponsa et al.	Native speakers	English & Spanish	Behavioral, ERPs	Peripheral pictures, arrays	Peripheral oddball paradigm	Visual	vMMN, P300	Preattentive visual object categorization & category labels
Maier & Abdel Rahman	Native speakers	German	Behavioral, ERPs	Pictures, labels	Object learning, consolidation	Visual	Accuracy; RTs; P1, N1, P2	Semantic processing & memorization of pictures & labels
Xue & Williams	Native speakers	Mandarin Chinese	Behavioral, ERPs	Written sentences, animations, pictures	Oddball paradigm	Reading, visual	Accuracy, vMMN, P300	Preattentive visual processing & grammatically conveyed transitivity
Wei et al.	Late bilinguals	Chinese–English	Behavioral, ERPs	Spoken words	Sound origin judgment	Auditory	Accuracy, RTs, P300 & N400	Metaphor embodiment in first & second language
Dobler et al.	Language learning simulation		Modeling	Neuron stimulation patterns representing words, visual input, & motor input	Training & testing of biologically constrained neural network model	Visual, motor, auditory, articulatory[a]	Spiking rate, peak activity, working memory period	Learning of abstract & concrete concepts

Note. The three main methodological approaches highlighted in this introduction to the special issue are symbolically separated by dotted lines. RT = reaction time; ERP = event-related potential; vMMN = visual mismatch negativity.

[a]The modalities listed are theoretical since they correspond to stimulation patterns presented to the "brain areas" of a large-scale neural network model.

The CoNSoLER Conference

This special issue of the Cognitive Neuroscience Series of *Language Learning* is based on an international conference held in the Faculty of English at Adam Mickiewicz University, Poznan, Poland, in October 2022, with the same title as this special issue (conference URL: https://consoler.web.amu.edu.pl/). The conference was attended by over 70 scholars from 17 countries and from a wide range of disciplines with a strong interest in how language is embodied and the implications of language diversity, from linguistic, psychological, neurocognitive, and computational viewpoints.

The quest for an optimal evidentiary basis to inform the debate is difficult, and many an experimental paradigm is often criticized on the basis that it provides insufficiently controlled stimuli or procedures to support strong conclusions. While language-based studies involving overt reports and questionnaires often fail to acknowledge that they cannot test cognitive effects beyond the realm of language, studies testing bilinguals systematically downplay the fact that the two languages of a bilingual individual are likely to be active at the same time. The debate, if there is to be one, thus calls for a triangulation of approaches that test the influence of verbal representations on cognitive processes that are not readily and mandatorily mediated by language (e.g., perception, memory, categorization), that tap into implicit processes that are mostly unconscious rather than strategic (e.g., somatotopic activation, visual perception), and that explore developmental trajectories (learning) as well as a linguistic diversity more representative of the world's population.

Having attended the conference and compiled the feedback received from delegates, we realized that CoNSoLER had met its objective to enable passionate interactions between delegates with highly different perspectives on embodiment and relativity. Keynotes were given by Rasha Abdel Rahman, Panos Athanasopoulos, and Friedemann Pulvermüller, and invited presentations were delivered by Johanna Kißler, Manne Bylund, and Monique Flecken. We also welcomed Lucia Pattullo, Morgane Peirolo, Rui Su, Norbert Vanek, Yuyan Xue, T. R. Williamson, Paweł Korpal, Connie Qun Guan, Yufen Wei, Aina Casaponsa, Martin Maier, Emiko Muraki, and Fynn Dobler, who were selected to give an oral presentation and all of whom were invited to contribute a paper to this special issue.

An Overview of the Contributions in the Special Issue

The first four papers of the special issue implement behavioral approaches to embodiment and linguistic relativity by recording patterns of response,

ratings, and/or reaction times in conditions where the participants are somewhat detached from language manipulations in order to test the effects of language forms in fundamentally nonverbal tasks.

Bylund et al. (2024) extended the investigation of language effects on perception to the domain of taste. Besides visual perception, other modalities have received little attention so far. Native speakers of Norwegian and native speakers of English were asked to taste samples of onions and garlic and rate them for similarity. Whereas garlic and onion share a label in Norwegian, they have distinct labels in English. Despite these crosslinguistic differences in the category boundaries, English and Norwegian speakers rated the taste of onion and garlic similarly. The authors conclude that the effects of language on perceptual experience, which have mostly been reported for vision, may not extend to the domain of taste. However, the intensity of the taste of bulbs may have overpowered the subtler effects of language on taste.

Sinkeviciute et al. (2024) also engaged their participants—Norwegian and Lithuanian speakers, as well as bilinguals fluent in the two languages—in similarity judgment tasks, but in this case regarding the color of visually presented patches of different shades of blue. The way in which bilinguals discriminated between these colors depended on the language of the task. In a Lithuanian language context, bilinguals discriminated between dark and light shades of blue more quickly than between similar shades within the same color category (for example, two slightly different light blues), in line with the linguistic distinction between *žydra* ("light blue") and *mėlyna* ("dark blue") in Lithuanian. However, in a Norwegian language context, the same bilingual individuals did not show a category effect, consistent with the lack of distinct color terms for lighter and darker shades in Norwegian.

Athanasopoulos and Su (2024) asked Chinese–English bilinguals to relate future and past events to front and back space in an adaptation of a temporal embodiment task (de La Fuente et al., 2014), manipulating context of operation and individual differences related to a major temporal landmark event involving the COVID-19 pandemic. Here, no embodiment effects were found either as a function of context or as a function of individual dispositions towards COVID-19. However, the latter variable did affect evaluative judgments of the past or the future. Those bilinguals who indicated more precautionary attitudes towards COVID-19 tended to value the future more than those bilinguals who displayed lower levels of precautionary attitudes. The fact that no such effect was found on embodiment per se points to a dissociation between conscious introspective behavior and unconscious embodiment and speaks to

the argument that the former should not be taken as proxy evidence for the latter (see our discussion earlier in this introduction).

Vanek and Zhang (2024) investigated how native speakers of Mandarin, native speakers of English, and second language learners of English align event boundaries with event-internal changes. In a nonverbal task, participants indicated the start and end point of events depicted by animations by manipulating visual sliders. Both native Mandarin speakers and learners of English set the boundaries further away from event transitions than native speakers of English. The authors deducted from this observation that Mandarin speakers may be less focused than English speakers on the segmentation of phases that immediately surround a transition in a motion event, which could be inferred from the way in which Mandarin Chinese but not English encodes ongoingness in its grammar.

The next four papers move from behavioral evidence to implicit measures of brain activity, namely event-related potentials (ERPs), less likely to be modulated in a strategic manner: ERPs provide indices of visual perception and unconscious information processing.

Casaponsa et al. (2024) presented native speakers of Spanish and native speakers of English with pictures of cups, mugs, glasses with a stem, and glasses without stems (regular glasses) in an oddball paradigm featuring one object type frequently (standard) and another rarely (deviant). The main (irrelevant) task was to detect a change in the appearance of the fixation cross presented in the center of the screen, while differences between objects only concerned peripheral (unattended) vision. The authors found that categorical differences marked by the participants' native language (*cup* vs. *mug* in English, *copa* vs. *vaso* in Spanish) resulted in visual mismatch negativity (vMMN) modulations, an index of automatic, preattentive change detection by the visual system. More to the point, such modulations were not observed when the participants' native language did not mark the distinction (*tazza* in Spanish, *glass* in English). This double dissociation across languages, within the same individuals, lends strong support to the idea that early stages of visual perception are affected by language terminology, one of the fundamental premises of linguistic relativity.

Maier and Abdel Rahman (2024) trained native speakers of German to categorize objects that either shared the same label, shared the same label and function, or shared the same function but were associated with an ever-changing nonword label. One group of participants was tested using an odd-one-out detection task immediately after meeting a reliability criterion for learning the categories, whereas another group was tested after a consolidation

period of 2–3 days. The authors found a right visual field categorical perception effect both immediately after learning and after consolidation, affecting the amplitude of early peaks of ERPs (P1, N1, and N2), elicited by a circular display of objects featuring either a within- or cross-category target. This result provides strong support for a causal role of language terminology in early categorical perception, since it was obtained in a learning paradigm when participants had no preexisting knowledge of the labels or the function of the objects presented (a fundamental difference from participants tested by Casaponsa et al., 2024).

Xue and Williams (2024) implicitly trained native speakers of Mandarin Chinese with novel morphological markers denoting transitivity, when neither their native language nor their second language (English) featured such grammatical markers. After exposure to a batch of training sentences using the new markers in a systematic fashion (experimental group) or in a random, fully rotated fashion (control group), participants performed a grammaticality judgment task that assessed their implicit learning of the new rule, and they then participated in a nonverbal priming task introduced as belonging to another, unrelated project. In each trial, participants saw a brief animation of a shape descending and interacting with another shape or falling alone, followed by a still picture symbolizing a motion event. In an oddball design manipulating the degree of matching between prime animation and target picture, the authors found that target pictures matching the animation in terms of object shape, but not transitivity, elicited a reduced P300 effect as compared to pictures matching the animation in terms of transitivity but not object shape (the P300 indexes spontaneous shifts of attention towards an infrequent, salient stimulus). A further test involving an oddball paradigm (following the same principle as that used by Casaponsa et al., 2024) showed that transitivity deviants elicited a vMMN modulation whereas object shape deviants did not. The authors concluded that implicit learning of a novel grammatical morpheme can immediately alter preattentive visual processing.

Wei et al. (2024) asked native speakers of Chinese with upper-intermediate proficiency in English and native speakers of English to indicate whether spoken words varying in perceived power (e.g., *king*, *slave*) were presented from a source situated above or below their sitting position. Whereas "low power" words failed to elicit a congruency effect, "high power" words perceived as originating from below elicited greater N400 amplitude than the same words presented from above (the N400 indexes semantic violations and incongruency). This predicted effect shows that the spatial metaphor for perceived power is embodied. However, this effect was found only in

Chinese–English bilinguals tested in Chinese and was not significant in the same individuals tested in English or native English participants tested in English. The authors interpret this effect as a sign that metaphor embodiment might not apply to the same extent in a language that is learned during adolescence compared to a language learned from birth. However, the absence of such an effect in the control group of native English speakers suggests that effects of culture may also be at play.

The special issue concludes with a modeling study commanding special attention: Dobler et al. (2024) report the results of a simulation employing a biologically constrained neural model to compare the semantic grounding of concrete and abstract concepts. Whereas training the model with concrete concepts linked to specific sensorimotor patterns of activation (introduced through visual and motor layers) fostered durable neural circuits characterized by significant and sustained activations, the assimilation of abstract concepts resulted in markedly diminished and ephemeral neural activity. However, the involvement of language representations (simulated through simultaneous input to auditory and articulatory layers of the model) markedly enhanced the circuit activations elicited by abstract concepts and resulted in comparable levels of activation to those observed for concrete concepts. These findings suggest that whereas the neural representation of concrete concepts likely stems from direct experiential grounding, the formation of abstract conceptual representations is facilitated by and even possibly requires the concurrent engagement of linguistic representations.

Where To From Here?

The insights featured in this special edition offer a glimpse of the confluence of language embodiment and relativity research, inviting scholars to envision potential directions for future exploration of the field. Stemming from the discussions at the CoNSoLER conference, which this issue draws upon, a critical idea emerges: Significant advancements in understanding embodied language and linguistic relativity require transcending the confines of a specific academic field of study to collaborate with experts from other domains and engage with bodies of knowledge outside that specific field. The importance of interdisciplinary collaboration might seem obvious (and, indeed, it is a powerful keyword in any research grant application), so it is quite astonishing to see the paucity of genuinely interdisciplinary research being conducted. This is perhaps more crucial in the case of language embodiment and relativity than in the case of many other subjects, because, as discussed above, there is a critical need for reciprocal engagement between scholars with an in-depth understanding of

linguistic forms, language mechanisms, and knowledge of language diversity, on the one hand, and scholars from experimental psychology and cognitive neuroscience, on the other hand, who can deliver hypothesis-driven paradigms testing modulation of implicit, nonverbal indices of perception and cognition, whether or not these can be considered preattentive.

Whereas testing brain correlates of taste and smell poses technical challenges that may be insurmountable, it is noteworthy that the other phenomena behaviorally investigated in this special issue have already been studied successfully using electrophysiological measures. For instance, Li et al. (2019), using ERPs, have found intriguing crosslinguistic differences in spatiotemporal metaphor embodiment in Chinese–English bilinguals, which speaks to the issue of embodiment of future and past in relation to space (Athanasopoulos & Su, 2024). Thierry et al. (2009) and Athanasopoulos et al. (2010) have shown vMMN modulations by language and exposure duration in the domain of color entirely consistent with the effects reported by Sinkeviciute et al. (2024). And an attentive reader may have already spotted parallels that can be drawn between the study by Xue and Williams (2024) looking at the consequences of morphological marking of transitivity for early, preattentive visual processing and that by Vanek and Zhang (2024) showing a relationship between the coding of ongoingness in Mandarin Chinese and the perception of event transitions.

Breaking new ground in the fields of language embodiment and linguistic relativity will probably require collecting data in controlled developmental, longitudinal contexts, in which exposure to linguistic information can be closely monitored, recorded, and quantified, thus allowing potential causal relationships between the key variables involved and the dependent variables to be rigorously tested. We confidently predict that nonverbal tasks and implicit testing will continue to flourish in this field, and that psychophysiological and neuroscientific data will progressively become the standard for demonstrating effects of language forms on perception and conceptualization.

Here are some questions that researchers might want to consider addressing in future studies:

- What if words that sound or look similar carried such formal overlap over to the conceptual domain, linking together the concepts they convey, a kind of hyper-Whorfian effect?
- What if the particular words that an individual chooses to describe more or less complex objects and situations made that individual more or less able to perceive them, recognize them, categorize them, and manipulate them?

- What if, on the contrary, the lack of a particular word or grammatical feature in the native language meant that a speaker of that language could not readily conceptualize a particular abstract object or situation in the same way as speakers of another language that has the word or feature in question (see, for instance, Li et al., 2018, 2023, for the case of grammatical tense and Chinese)?
- What if verbal and nonverbal conceptual representations implemented by neural networks in the human brain interacted with the networks in charge of early stages of perception to a much greater extent than scholars have been able to understand?
- What if language did more than superficially orient attention to features of the world and also contributed to unconsciously shaping human behavior?

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