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Linguistic Priors for Perception

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Abstract

In this commentary, we approach the topic of linguistic relativity from a predictive coding perspective. Discussing the role of "priors" in shaping perception, we argue that language creates an important set of priors for humans, which can affect how sensory information is processed and interpreted. Namely, languages create conventionalized conceptual systems for their speakers, mirroring and reinforcing what is behaviorally important in a society. As such, they create collective conceptual convergence on how to categorize the world and thus "streamline" what people rely on to guide their perception.

Keywords: Language; Priors; Predictive coding; Crosslinguistic differences

Perceptual systems are not isolated modules in the brain. Rather, they are in constant interaction with higher-level processes and representations, such as attention, expectation, or prior and contextual knowledge, making them susceptible to a number of top-down influences (Gilbert & Li, 2013). This means that we see the world through the lens of preconceived notions stored in our mind. In other words, nothing that we perceive in the world around us is an impartial reality; rather, what we see largely depends on the individual's prior experiences and knowledge, not only of long-term (accumulated over time) nature, but also of immediate

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(in the moment) nature, in which information presented mere (milli)seconds before sensory input can bias how the input is interpreted (De Lange, Heilbron & Kok (2018)). Knowing that we rely on prior experiences to guide our perception, we argue that languages create a particularly important set of priors for humans. These linguistic priors can affect how we organize conceptual knowledge, and how we perceive and interpret sensory information in the context of that knowledge. We approach Kemmerer's proposal, that different languages can differentially affect perception, from the predictive coding point of view, and argue that linguistic influences on perception should be viewed as a subset of more general top-down effects on sensory processing. Research on language−perception interaction can benefit from what we know about top-down modulation of perception more generally, in particular from our still-growing understanding of the underlying neural machinery and temporal profiles of such effects.

The idea of priors guiding our sensory processes traces back to the notion of the "predictive brain" (e.g., Friston, 2010): our cognitive and perceptual systems operate on experience accumulated throughout our lifetimes. They estimate the likeliest future state of our surroundings, while keeping track of differences between the internal prediction model and the sensory information at hand through computation of prediction error. Through the loop of predictions and prediction-error-based adaptations, we learn to perceive the world around us through the lens of statistical probabilities and most-likely scenarios in any given context. In fact, one can say that our prior experiences and the predictions that we generate on the basis of those experiences are crucial for our ability to make sense of the world.

As an example, Hardstone et al. (2021) provided evidence that long-term knowledge can shape how we perceive ambiguous images via top-down neural modulation. Using electrocorticography, they showed that, when perceiving bi-stable images, a more commonly experienced percept is accompanied by an increase in top-down, temporo-occipital activity. A less common percept, on the other hand, was accompanied by an increase in bottom-up activity along the same pathways. Going a step further, long-term priors can even be encoded in the very neural structure of regions that process sensory input (Hardstone et al., 2021). For example, neurons tuned to cardinal orientations and centrifugal motion direction in early visual areas outnumber neurons tuned to less salient orientation and motion directions, suggesting that statistically relevant information also dictates how many resources in the brain we have available to encode the information in the first place (Albright (1989); Li, Peterson, & Freeman (2003)).

Different types of long-term priors, such as visual priors (e.g., familiarity with faces; Dolan et al., 1997), action priors (e.g., knowledge on how to handle objects; Gerson, Bekkering & Hunnius (2015)), and priors based on our experiences with events in the world (e.g., the relations that exist between entities and objects; Scholl & Tremoulet, 2000; Radvansky & Zacks, 2017), have been shown to shape our perception in the predictive coding literature. Like these types of priors, language can create a conventionalized knowledge base for its speakers, mirroring and reinforcing what is behaviorally important in a society and creating collective conceptual convergence on how to categorize the world in a given community. As such, they have the power to, to a certain extent, streamline what people default to when relying on prior information to guide their perception. In other words, they create molds, pathways, and common denominators that humans rely on to categorize what they experience. In this sense, the categories, as shaped by the linguistic environment(s) we grow up in, function as long-term priors similar to other types of priors that shape perception, and that develop throughout infant- and childhood as our experiences with the world grow. Research indeed shows that (nonlinguistic) priors can differ between individuals, based on, for example, their level of expertise on a topic (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). Knowing this, it makes sense to assume that crosslinguistic differences in semantic or grammatical categories lead to differences in the language-induced priors that people rely on. As an example, languages differ in the level of granularity at which they represent actions linguistically, for example, English speakers use the verb *to open* for a variety of actions, such as opening a door, opening one's eyes, but these are encoded using different verbs in Korean (Bowerman, 2005). Additionally, the features that are relevant to semantic categorization differ across languages, creating unique sets of categories, each of which consists of concepts bound together by common denominators not necessarily found in other languages. For example, going back to the action of *opening*, languages may differ in how they group concepts around that action, ranging from interpreting the act of opening in Phyelchita as *spreading out a flat thing* (the action of opening a book is in the same category as spreading out a blanket) to interpreting it in Ttuta as (at least partially) synonymous with *rising* (placing the act of opening one's eyes in the same category as the sun rising; Bowerman, 2005). Experiences with different language systems may thus lead to cross-linguistic differences in the top-down modulation of perception of the relevant actions, objects, or events.

Recognizing that language is one of many types of priors, and a highly potent one at that (Edmiston & Lupyan, 2015; Lupyan & Spivey, 2010), opens up an opportunity to approach language−perception interaction in the context of research looking into cognitive and neural mechanisms underlying top-down influences on perception in general. The research focus can, therefore, shift from discussing whether language influences perception in both the long-term and short-term sense to research on *when* and *how* language affects how we perceive the world. With that shift, we can start acknowledging diversity, not only across languages, but also the diversity of cognitive and neural signatures subserving such top-down effects in different contexts. For example, we know that, neurally, perceptual processes can be modified in a number of different ways—from subtle spatial (Francken, Kok, Hagoort & De Lange (2015); Pirog Revill, Aslin, Tanenhaus & Bavelier (2008); Puri, Wojciulik, & Ranganath (2009)) or temporal (Boutonnet & Lupyan, 2015; Hirschfeld, Zwitserlood & Dobel (2011); Landau, Aziz-Zadeh, & Ivry (2010); Noorman, Neville, & Simanova (2018)) shifts in neural activation, to different types of neural activation profiles (neural enhancement, neural suppression, or neural sharpening, Kok, Jehee & De Lange (2012); Kok & de Lange, 2014; Richter & de Lange, 2019; Summerfield & de Lange, 2014), to different types of (behavioral) effects altogether (changes in speed or accuracy, changes in discriminability between categories, or changes in bias toward the expected percept, see Slivac, 2022), or even changes in the direction of influence (facilitation or "attractive influence" in the detection of congruent stimuli vs. inhibition or "repulsive influences," noticed in studies on color and motion aftereffects (Dils & Boroditsky, 2010; Zheng, Huang, Zhong, Li, & Mo (2017)). In sum, we should step away from an all-or-nothing approach when it comes to language−perception interaction and start to systematically map out the ways in which different languages can affect our perception, studying carefully their underlying neural signatures and the time course of such top-down modulations. In order to do that efficiently, we echo Kemmerer's (2022) argument that neurolinguistic research must embrace more sophisticated—multivariate—statistical approaches, that allow us to map out the richness of neural mechanisms subserving (linguistic) top-down influences on perception.

Finally, when considering the influence of any prior, including linguistic, we have to be aware of the subtlety of such effects, both behaviorally and neurally. Language, just as any other prior, will not *drastically* change what we are able to see. However, given the noisiness of our everyday lives, they might make us rely on what is statistically most likely in any given context, and what is statistically most likely might very well be reinforced through language and the systematicity in the concepts and categories encoded therein. It is no surprise then that an effect of language on perception is strongest or qualitatively different when we are in the presence of ambiguous sensory information or when we are under time pressure to quickly discern what is in front of us (Slivac, Hervais-Adelman, Hagoort & Flecken (2021); Kok & Turk-Browne (2017)). In line with the subtlety of such effects, we circle back to the necessity to focus on fine-grained differences in neural activation patterns evoked by language, examinable through multivariate pattern analysis approaches, such as representational similarity analysis or machine learning. In other words, rather than expecting drastic changes in neural activation patterns as a function of slightly different conceptual systems, we should focus on subtle shifts in processing time or neural space. As subtle as they may be, they still might play a crucial role in making us default to a certain percept based on the most salient prior.

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