

Transient and lasting linguistic influences on visual perception: shifting brain dynamics with memory consolidation

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Evidence accumulates that language influences perception (Lupyan et al. 2020). For instance, if two objects or colors are called differently, they stand out more against each other (Maier et al. 2014; Maier & Abdel Rahman 2018). This categorical perception effect can improve discrimination and even conscious detection of stimuli that straddle a linguistic category boundary (Maier & Abdel Rahman 2018; Regier & Kay 2009). Still, the neurocognitive dynamics of linguistically modulated perception are not yet well understood. Does language influence visual perception through transient online modulations or by inducing lasting changes to visual mental representations?

We used EEG to test how effects of newly acquired linguistic categories differ before versus after memory consolidation during sleep. In two experiments, participants learned to associate unfamiliar objects with new category labels. They then performed a visual search task in which they indicated the position of one deviant object displayed together with eleven identical distractors (left vs. right visual field). In Experiment 1, there was a two-day break between category learning and the visual search task, allowing for memory consolidation of object labels and their association with objects. In Experiment 2, the visual search task immediately followed the learning routine, strongly limiting memory consolidation. Reaction times and single trial amplitudes of event-related potential (ERP) components reflecting low- and high-level vision (P1 and N1 component), as well as attentional selection (N2 component) were analyzed with linear mixed models.

Faster reaction times for between- compared to within-category trials confirmed a behavioral categorical perception effect. ERPs revealed distinct neural dynamics of categorical perception before vs. after memory consolidation, which were largely restricted to the right visual field, tying the effects to left-hemispheric language structures of the brain. Directly after category learning, N1 amplitudes were larger in within-category search trials. Thus, language can influence visual processing almost instantaneously, with limited memory consolidation. Then, visual processing dynamics shifted significantly and became more varied with memory consolidation. The N1-effect switched polarity, with larger amplitudes in between-category search trials, such that it aligned with the canonical “visual mismatch negativity” effects reported in studies using familiar stimuli well-established in long-term memory (Boutonnet et al. 2013; Thierry et al. 2009). In addition, an even earlier effect in the P1 component emerged only with memory consolidation, suggesting increased efficiency or automaticity of linguistically modulated perception. A category effect also emerged in the N2 component, suggesting that increased attention to between-category targets comes with consolidation.

Our results show that memory consolidation is a crucial factor shaping how linguistic categories modulate perception. We interpret these shifting dynamics to reflect fast transient modulations of configural visual processing at first (N1), and more lasting effects on various stages throughout the visual processing stream, including low-level feature processing (P1) as linguistic knowledge settles into memory. Language appears to induce both, instantaneous transient modulations, as well as long-term changes to visual perception. In line with previous evidence, including inter-area connectivity observed with fMRI (Schmidt et al. 2019), we propose that language- and sensory areas of the brain form networks to instantiate combined visuo-linguistic representations that are long-lasting and efficient, but can still be interfered with if language is disrupted (e.g., with verbal interference; Winawer et al. 2007).

References

- Boutonnet, Bastien, Benjamin Dering, Nestor Viñas-Guasch & Guillaume Thierry. 2013. Seeing Objects through the Language Glass. *Journal of Cognitive Neuroscience* 25(10). 1702–1710. https://doi.org/10.1162/jocn_a_00415.
- Lupyan, Gary, Rasha Abdel Rahman, Lera Boroditsky & Andy Clark. 2020. Effects of Language on Visual Perception. *Trends in Cognitive Sciences* 24(11). 930–944. <https://doi.org/10.1016/j.tics.2020.08.005>.
- Maier, Martin & Rasha Abdel Rahman. 2018. Native Language Promotes Access to Visual Consciousness. *Psychological Science* 29(11). 1757–1772. <https://doi.org/10.1177/0956797618782181>.

- Maier, Martin, Philipp Glage, Annette Hohlfeld & Rasha Abdel Rahman. 2014. Does the semantic content of verbal categories influence categorical perception? An ERP study. *Brain and Cognition* 91. 1–10. <https://doi.org/10.1016/j.bandc.2014.07.008>.
- Regier, Terry & Paul Kay. 2009. Language, thought, and color: Whorf was half right. *Trends in Cognitive Sciences* 13(10). 439–446. <https://doi.org/10.1016/j.tics.2009.07.001>.
- Schmidt, Timo Torsten, Tally McCormick Miller, Felix Blankenburg & Friedemann Pulvermüller. 2019. Neuronal correlates of label facilitated tactile perception. *Scientific Reports. Nature Publishing Group* 9(1). 1606. <https://doi.org/10.1038/s41598-018-37877-w>.
- Thierry, G., P. Athanasopoulos, A. Wiggett, B. Dering & J.-R. Kuipers. 2009. Unconscious effects of language-specific terminology on preattentive color perception. *Proceedings of the National Academy of Sciences* 106(11). 4567–4570. <https://doi.org/10.1073/pnas.0811155106>.
- Winawer, Jonathan, Nathan Witthoft, Michael C. Frank, Lisa Wu, Alex R. Wade & Lera Boroditsky. 2007. Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences* 104(19). 7780–7785. <https://doi.org/10.1073/pnas.0701644104>.