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Verbal labels facilitate tactile perception

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ABSTRACT

One of the key statements of linguistic relativity is that language has a causal effect on perception. Although much previous research has addressed such putative language perception causality, no firm proof is available thus far which demonstrates that verbal labels help or otherwise influence perceptual processes. Here, we tested the hypothesis of language perception causality by using novel, minimally-different tactile-patterned stimuli applied to the finger, which initially could not be discriminated by our participants. By combining novel verbal pseudoword- and novel tactile-patterned stimuli in an implicit learning experiment, we show a language-induced facilitation in tactile-patterned stimulus discrimination. After one week of intensive yet implicit learning of tactile stimuli in the presence of irrelevant consistent verbal labels, participants demonstrated significant discrimination improvement. In contrast, the same participants showed no improvement in discriminating tactile-patterned stimuli that had been learnt in the context of variable linguistic stimuli. These results show that specific mental links between verbal labels and perceptual information brought about by their correlated presentation enable one to better discriminate said sensory information (and build percepts).

1. Introduction

Few issues have caught more attention in the language sciences than linguistic relativity, the idea that language influences perception, cognition, and thought (Carroll, 1956; Gentner & Goldin-Meadow, 2003; Kay & Kempton, 1984; Sapir, 1921; von Humboldt, 1836; Whorf, 1940). Different researchers cast the precise claims behind this general framework quite differently (Boroditsky, 2001; Firestone & Scholl, 2015; January & Kako, 2007; Lucy, 1997, 2008; Slobin, 1996); for example Lupyan, Rakison, and McClelland (2007) and Maier, Glage, Hohlfeld, and Abdel Rahman (2014). However, one of the key implications of linguistic relativity is that there is a causal link between structural properties of a language, e.g. its vocabulary items, and the language users' cognitive processes contributing to perception. Using one famous example for illustration, Hopi Indians are purported to have an easier time discriminating between shades of red because their language structurally represents different such shades as corresponding vocabulary items (Whorf, 1938), that is, as monomorphemic high-frequency words. Here, we address the hypothesis that language causally affects perceptual discrimination, which we label the *language perception causality (LaPeC)* statement. This claim has led to heated debates in the past, involving linguists who pointed to flawed conceptual distinctions and false empirical claims (see, for example, Pinker, 1994) and experimentalists reporting new exciting results (see discussion below).

Arguments supporting the LaPeC hypthesis can be found in the accumulating evidence of cross-linguistic differences in perception of colours (Mo, Xu, Kay, & Tan, 2011; Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009; Winawer et al., 2007), motion events (Athanasopoulos et al., 2015; Flecken, Athanasopoulos, Kuipers, & Thierry, 2015; Meteyard, Bahrami, & Vigliocco, 2007; Thierry et al., 2009), and shapes (Boutonnet, Dering, Viñas-Guasch, & Thierry, 2013; Lupyan, 2008), which could, in part, be related to linguistic structures of the participants' native languages (Boutonnet et al., 2013; Majid, Bowerman, Kita, Haun, & Levinson, 2004; Meteyard et al., 2007; Thierry et al., 2009; Winawer et al., 2007). However, these putative effects of language on perception are open to alternative explanations, as most of the studies focused on naturally acquired languages (Lupyan & Ward, 2013; Meteyard et al., 2007; Thierry et al., 2009; Winawer et al., 2007). Effects might therefore be explained by linguistic relativity ideas, but the influence of other factors cannot be excluded with

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certainty, for example that of differences in living conditions or culture-specific knowledge and skills (Armstrong, Gleitman, & Gleitman, 1983; Freundlieb et al., 2012; Gleitman & Papafragou, 2005; Li & Gleitman, 2002; Zhou et al., 2010).

To illustrate these issues, let us consider one previous study in detail. In 2007, a famous paper reported that native speakers of Russian, which has different words for the colours light and dark blue (*siniy, goluboy*), were faster to discriminate variants of blue which lay on different sides of the categorical linguistic boundary between the colour spaces denoted by these words, compared to shades of blues covered by the same linguistic expression. English speakers showed no similar difference in discriminating these variants of blues (Winawer et al., 2007). Because Russian, but not English, has different labels for the relevant shades of blue, this difference in discrimination performance may be linked to structural properties of these languages. However, critics may attribute this difference to variance in discrimination abilities of the participant populations, which could be related, for example, to differences in previous perceptual experience or cross-cultural conceptual differences. As, strictly speaking, these differences do not ultimately rule out perceptual experiences or culturally-imposed nonlinguistic knowledge and habits as factors (influencing the reported effects), these results leave many still skeptical about linguistic relativity in general (Pinker, 1994) and LaPeC specifically (Devitt & Sterelny, 1999; Firestone & Scholl, 2015).

Putative effects of perceptual experience and pre-existing knowledge can be controlled in experiments targeting the learning of new concepts or words. Indeed, a number of recent studies have used training paradigms to study possible effects of novel word learning on cognitive capacities such as categorisation. For example, Lupyan et al. (2007) trained participants to distinguish between approachable and nonapproachable 'alien creatures'. These categories could be learned based on visual information alone, so categorical labels were not necessary for the task. However, when stimuli falling into either category were accompanied by redundant nonsense verbal labels (pseudowords), their categorization was learned more quickly than when such labels were absent. Note that the correct categorization was learned equally well, but slightly faster when there was a secondary label. Note furthermore that subjects were told to "pay careful attention" to redundant labels, which introduces attention as a further possible factor that could explain the observed effects. Another study looked at whether bilinguals perform differently in a categorization task dependent on which language they are operating in (Athanasopoulos et al., 2015). Based on previously described cross-linguistic differences in motion encoding between English and German, this study demonstrated that the language of operation invoked a bias in categorizing real-world videos with more or less goal-orientated motion. Due to the complexity of the applied stimuli, the effect is unlikely to be driven by perceptual differences but rather by differences in categorical classification. Here, we propose a study that focuses not on participants' ability to categorize stimuli as being similar or dissimilar to one another, but on their ability to perceptually discriminate two very similar percepts.

The observation that new objects could be learned to be categorized more quickly when appearing with redundant labels indicates an influence of language on categorization (Lupyan et al., 2007). Interestingly, a recent ERP study showed a concordant modulation of the P100 component reflecting the difference in categorization between labelled and unlabelled conditions (Maier et al., 2014). Other studies have investigated whether training could reverse the effect of the presence of labels by looking at cross-linguistic differences (Dolscheid, Shayan, Majid, & Casasanto, 2013). This captivating research has focused on perception of stimuli which are easily distinguishable, and addressed the learning to conceptually categorize such easily perceived and discriminated stimuli as belonging to one group or another. However, improvements in conceptual categorization do not necessarily stem from improved perception. Alternatively, participants might have improved in the identification of the decisive categorization criteria without any change in the stimulus perception per se. In contrast, an improvement in a perceptual discrimination tasks constitutes a direct measure of low-level perceptual differences. Therefore, the summarized studies do not address the LaPeC hypothesis about a direct influence of language on the perception of stimuli.

In summary, research performed to date has demonstrated interesting correlations between language and aspects of perception and cognition, though not a *causal* relationship of language on perception as posited by the LaPeC hypothesis. To address the latter, it is therefore necessary to perform experiments where all participants are exposed to the same novel stimuli, both linguistic and perceptual, and where within-subject manipulation can be studied to rule out any effects of group or population differences. Implementing an implicit learning design where the same participants engage in different learning conditions appears to open a research pathway toward addressing effects of language on perception. Note again that it is important to exclude familiar labels, due to their pre-existing semantic links and embedding into general knowledge and skills. It is equally important to use stimuli which are difficult to distinguish from one another in order to test for any improvement in how they are perceived and recognized.

To this end, we implemented a study in which novel associations were formed between language labels and precepts. To test if the consistent association of a label influences perception, we implemented a discrimination task using pre-selected stimuli that were difficult to distinguish, making sure that subjects initially performed around chance level before consistently associating a label. This allowed us to test if the consistent pairing of task-irrelevant labels to tactile-patterned stimuli in an implicit learning paradigm improves discrimination abilities compared to a variable association, thereby demonstrating a causal effect of language on perception.

Tactile perception offers a unique domain for testing LaPeC. By using tactile-patterned stimuli, we venture outside of the long-researched domain of visual perception to a new perceptual modality for the following reasons: (1) in the typical population, referential semantic links between words and tactile patterns are rare in languages such as English or German (outside of specialized fields, only few instances such as 'rough', 'smooth' exist, but specific patterns such as the ones in Fig. 1 do not have specific labels); (2) this modality allows us to investigate minimal, fine-grained differences that are hard to be discriminated and thereby allow the measurement of fine improvements over a training period without fast ceiling effects. By using very similar tactile patterns and controlling for effects of the amount of exposure, we are able to test whether consistently labelling said patterns leads to a greater improvement in their perception than mere exposure with variable labels alone.

To address the LaPeC hypothesis, the present study applied novel, meaningless linguistic stimuli (pseudowords) and correlated them with novel, minimally different tactile-patterned stimuli. The stimuli were learnt in a stimulus recognition task where subjects had to press a button to identify occasional repetitions. Verbal labels were not relevant for tactile stimulus recognition, but were merely redundantly co-presented with the tactile stimuli, thus allowing for implicit stimulus association. Crucially, we implemented systematic, consistent pairings of tactile-patterned stimuli with specific (but task irrelevant) pseudowords, whereas a control condition looked at perceptual stimulus discrimination in the context of more generally used labels, which co-occurred with variable patterns. Based on the LaPeC hypothesis of a causal influence of language on perception, we predicted that tactile-patterned stimuli that are consistently paired with specific pseudowords will have a perceptual advantage over those presented in the control condition where each meaningless pseudoword occurred together with several different perceptual patterns.