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Seeing odors in color: Cross-modal associations in children and adults from two cultural environments

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ABSTRACT

We investigated the occurrence and underlying processes of odor–color associations in French and American 6- to 10-year-old children (n = 386) and adults (n = 137). Nine odorants were chosen according to their familiarity to either cultural group. Participants matched each odor with a color, gave hedonic and familiarity judgments, and identified each odor. By 6 years of age, children displayed culture-specific odor–color associations, but age differences were noted in the type of associations. Children and adults in both cultural groups shared common associations and formed associations that were unique to their environment, underscoring the importance of exposure learning in odor–color associations.

Introduction

Odors are most often experienced in a multisensory context. While eating, for example, odors of foods are delivered retronasally to the olfactory receptors and experienced concurrently with taste, texture, and temperature along with visual and auditory information about the sources of the odors. This rich multisensory experience affords ample opportunities for forming or reinforcing associations between odors and their correlated sensory qualities. The study of these associations can enhance our understanding of the developmental processes underlying multisensory integration in general.

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The current study examined developmental and cultural variations in cross-modal associations between odors and colors. The odors we encounter in everyday life are indeed typically associated with specific colors; for example, lemon odor evokes an association with the color yellow. Numerous studies have reported nonrandom and reliable odor–color associations in adults (Demattè, Sanabria, & Spence, 2006; Gilbert, Martin, & Kemp, 1996; Jacquot, Noel, Velasco, & Spence, 2016; Levitan et al., 2014; Maric & Jacquot, 2013; Schifferstein & Howell, 2015; Spector & Maurer, 2012). These studies suggest that odor–color associations are partly based on semantic knowledge (identity, familiarity, and category) of the source objects of the odors, indicating the primordial influence of experience with explicitly identified odors. In other cases, odor–color associations seem to be based on perceptual qualities of the stimuli such as intensity (e.g., darker colors associated with more intense smells; Kemp & Gilbert, 1997) and hedonic value. Consistent odor–color associations have also been reported when the odor was unfamiliar or did not reflect an obvious real odor "object" (e.g., mushroom odor with blue; Spector & Maurer, 2012).

Spence (2011) proposed that odor–color associations emerge from statistical, semantic, or structural processes. Statistical associations reflect the frequency of encounters between a specific odor and the color of its referent object. For example, for Western populations, the odor of lemon becomes associated with the color yellow because of repeated co-perception of the yellow item and its odor. Semantic associations pertain to the sharing of identity or meaning between stimuli. The odor and color of lemon are associated in semantic networks with the verbal label "yellow." Finally, structural associations arise from the intrinsic organization of the perceptual system and are based on common neural correlates. For example, odors and colors can be associated when they share a feature such as intensity or magnitude. Both statistical and semantic associations are thought to be learned, contrary to structural associations that are thought to form independently of direct experience with the odor and its referent. Statistical associations may reflect the color linked with an odor (e.g., yellow = lemon odor), whereas structural associations may be demonstrated by the association of color cues (e.g., brightness, saturation) with congruent odor properties (e.g., intensity, pleasantness). To date, there is strong evidence supporting statistical and/or semantic bases of odor–color associations in adults (e.g., Levitan et al., 2014; Nehmé, Barbar, Maric, & Jacquot, 2016), including in a hunter–gatherer sample (de Valk, Wnuk, Huisman, & Majid, 2016) along with some evidence of a structural basis in some cases (Kemp & Gilbert, 1997).

Recent intercultural comparisons in adults have reported more consistent odor–color associations within different cultures than between them, supporting the idea that odor–color correspondences depend on semantic or statistical learning of associations that are more commonly encountered within a particular cultural context (Jacquot et al., 2016; Levitan et al., 2014; Nehmé et al., 2016). For example, Nehmé et al. (2016) reported that pineapple odor was associated with yellow by a Taiwanese sample but with red by a French sample, presumably because of its frequent encounter with other sweet fruits.

To date, the literature on odor–color associations has relied exclusively on adults, leaving the development of odor–color associations undocumented. Children are, however, capable of multimodal associations in other sensory domains (see Bremner, Lewkowicz, & Spence, 2012). For example, associations between sound and visual objects have been observed from 3 or 4 months of age (Dolscheid, Hunnius, Casasanto, & Majid, 2014; Walker et al., 2010), between touch and color patches from 5 years (Ludwig & Simner, 2013), and between shape and color of letters in toddlers (Spector & Maurer, 2008, 2011). There is a debate as to whether these associations are of the structurally mediated type (Spector & Maurer, 2013) or whether there are alternative statistical or semantic explanations (Deroy & Spence, 2013).

A closer developmental focus on odor–color associations is needed to document whether and when such associations are formed and how they change with age. Studying development is also a strategy to understand the basis for odor–color associations, that is, the conditions of their detection, learning, retention, expression, and effective use in various domains where odor–color expectations may prevail (e.g., object or toy preferences; selection of fabrics, food, and beverages; cosmetics; environmental enjoyment).

The first goal of this study was to document the occurrence of nonrandom odor–color associations in children and explore developmental differences in these associations. This study is a first attempt to