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Music and Odor in Harmony: A Case of Music-Odor Synaesthesia

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Abstract

We report an individual with music-odor synaesthesia who experiences automatic and vivid odor sensations when she hears music. S's odor associations were recorded on two days, and compared with those of two control participants. Overall, S produced longer descriptions, and her associations were of multiple odors at once, in comparison to controls who typically reported a single odor. Although odor associations were qualitatively different between S and controls, ratings of the consistency of their descriptions did not differ. This demonstrates that crossmodal associations between music and odor exist in non-synaesthetes too. We also found that S is better at discriminating between odors than control participants, and is more likely to experience emotion, memories and evaluations triggered by odors, demonstrating the broader impact of her synaesthesia.

Keywords: synaesthesia; odor; music; crossmodal associations

Introduction

When we listen to music, we often experience strong feelings of emotion (Zentner, Grandjean, & Scherer, 2008). Similarly, a song might activate a personal memory (Janata, Tomic, & Rakowski, 2007). Despite agreeing that music can be a comfort, W. H. Auden pronounced in the poem *In Praise of Limestone* that music "can be made anywhere, is invisible, and does not smell". Should we accept such a bold statement about the unitariness of music? Here we investigate associations between music and odor. Similarities between the two have been raised before: for example, like music, perfumes are described as having "notes" and "composition". We report for the first time an individual with music-odor synaesthesia who experiences strong and automatic olfactory percepts when hearing music.

Synaesthesia, is a neurological phenomenon where people experience automatic and vivid associations between the senses (for review see Rich & Mattingley, 2002). Synaesthesia involving music has been reported before, with music eliciting vivid visual experiences; such as music-color synaesthesia (Marks, 1975; Ward, Huckstep, & Tsakanikos, 2006). One of the earliest mentions of such phenomena can be found in Locke (1690), where a blind man describes the color scarlet to be "like the sound of a trumpet".

Synaesthesia involving the chemical senses, on the other hand, is rare. There have been reports of synaesthetic associations elicited by odors; e.g., odor-color synaesthesia (Speed & Majid, 2018). There is also evidence of synaesthetic concurrents occurring within the chemical senses, such as taste: e.g., E.S. experiences tastes on her tongue when she hears music-tone intervals (Beeli, Esslen, & Jancke, 2005). There are also synaesthesias with odor as the concurrent experience. For one individual, environmental sounds elicited smells; e.g., the sound of a drill smells like bleach (Jackson & Sandramouli, 2012). In another unusual case, L.J. experiences olfactory associations to congruent visual stimuli (Chan et al., 2014); e.g., the image of a leather shoe smells like leather.

Research in olfaction has highlighted that naming odors is difficult (Cain, 1979; Majid & Burenhult, 2014), and people are poor at conjuring mental images of odors (Crowder & Schab, 1995). There is also a suggestion that language may not activate olfactory information as specifically as language in other perceptual modalities (Speed & Majid, in press). Overall, then, access to olfactory representations appears to be limited. This makes individuals who experience olfactory sensations in the absence of real odors of great interest.

Music-odor associations have been reported in non-synaesthetes. For example, Crisinel and Spence (2012) found people matched certain odors to specific types of musical instrument, such as the odors apricot and blackberry to the sound of a piano. Odors were also consistently associated to musical pitch, with matches determined by the pleasantness and complexity of the odor (Crisinel & Spence, 2012). Similarly, Levitan, Charney, Schloss, and Palmer (2015) reported odor matches to a diverse range of music, such that the odor of cloves and the sound of an Indian sitar had the strongest association.

Here we present for the first time synaesthete S who has music-odor synaesthesia. In a first experiment, in order to learn more about S's music-odor experiences, odor associations to a variety of music clips were recorded over two separate days in S and two controls. In Experiment 2, a new set of participants rated the similarity of odor descriptions provided in Experiment 1, to assess consistency of music-odor associations. We predicted S's associations to the same music clip (and possibly the same instrument) would show greater consistency than controls. Finally, we tested whether music-odor synaesthesia affects aspects of odor cognition by comparing S's performance on a number of odor tasks with that of a control group.

Experiment 1: Eliciting music-odor associations

Method

Participants S is 38-year-old female with multiple forms of synaesthesia. She works as a PR consultant but also designs fragrances in her spare time. She describes her world as one in which sensory experiences move between smell, music, color, texture and numbers. Here we focus on her music-odor associations. Her synaesthetic odor experiences appear to be quite specific. Here she describes one such episode: "For example one summer I listened to Muse, "Undisclosed desires". It was for me an obvious metallic, iron, berry song and I developed the idea and composition for a fragrance in my head with that idea as structure". Two age- and gender-matched control participants without synaesthesia were recruited from the Radboud University participant pool.

Material Music was taken from an online music database (freemusicarchive.org). In order to sample a variety of music, a total of 34 sound clips were used. There were 12 clips from different genres of music (involving multiple instruments), and 12 clips from individual instruments, with a regular and speeded version edited using Audacity (except for two instruments for which the speeded versions were not clear). By using regular and speeded versions of the clips, we could test to what extent associations are based on features such as timbre, or instead features such as tempo.

Procedure Testing took place on two separate days with a one-day break in between. The experiment was conducted using E-prime. In each session, participants listened to all music-clips through headphones. The clips were presented in a random order, and each clip was played only once per session. The music continued to play until the participant pressed the Enter key to begin their response. S was instructed to describe her synaesthetic odor experiences and control participants were instructed to describe any odor associations they had to the music. Participants typed in their responses, and were free to leave a response empty if they had no associations.

Results

A repeated measures ANOVA by items revealed a significant difference between participants in the number of words used per odor description, $F(2, 66) = 31.02$, $p < .001$, $\eta_p^2 = .49$. S used significantly more words in her descriptions than Control 1 (C1) (5.93 vs. 3.25, $p < .001$) and Control 2 (C2) (5.93 vs. 1.66, $p < .001$). There was also a significant difference between controls with C2 being particularly succinct (3.25 vs. 1.66, $p = .004$).

S's odor associations tended to be of "smellscapes" rather than individual odors; for example, one response was "caramel, tea, metal, water, ambergris, wood, cookies". In contrast, the majority of control odor associations were single odors. There was also a marked difference in the ease of reporting odor associations. S's odor associations came easily and vividly, whereas controls often struggled to make an association. C1 responded "no smell" 10 times across both days, and C2 gave no response twice. S gave responses for all sounds.

Since S gave multiple responses, it is possible she was randomly generating odors. One way to check if there is systematicity in the odors associated to music is to map similarity of musical stimuli as a function of their odor associations. To explore this, we created a binary 34-by-34 matrix of musical stimuli based on shared odor associations. For example, cello and saxophone were both said to smell like tea, and so were coded as similar. If no shared odor association appeared, the musical pair was coded as dissimilar (i.e., binary coding). Separate similarity matrices for each participant were created and submitted to multidimensional scaling (MDS) using the ALSCAL algorithm in SPSS (Version 22) (see Figure 1). Controls showed little systematic association (as indicated by the large cluster of items loading 0). However, S's odor associations indicated greater systematicity, with items differentiating across two dimensions. For example, double bass, drums, fast electric guitar and reggae all received similar odor associations (e.g., they all evoked the odor of honey), as did bagpipes, electric guitar, piano and punk (which all evoked the odor of metal). This indicates S's—but not C1's and C2's—odor associations are sensitive to types of musical instrument/genre.

Experiment 2: Rating music-odor associations

Are music-odor associations consistent for S and controls? To quantify this, a new set of participants read pairs of odor associations and rated their similarity. We predicted associations would be more consistent across the two testing days for the synaesthete than controls.

Method

Participants Thirty participants were recruited on Amazon Turk (14 females; M_{age}=34.7, *SD*=9.59) to rate descriptions given by S and controls.

Procedure Participants were given pairs of odor associations from either the same sound clip presented on both days (identical condition), same instrument at different speeds (instrument condition), or random pairings of descriptions (random condition). Participants were instructed to rate how similar pairs of smell descriptions were on a scale of 1 to 100 by clicking on a visual analog scale. All descriptions from S and controls were randomly presented in one session.

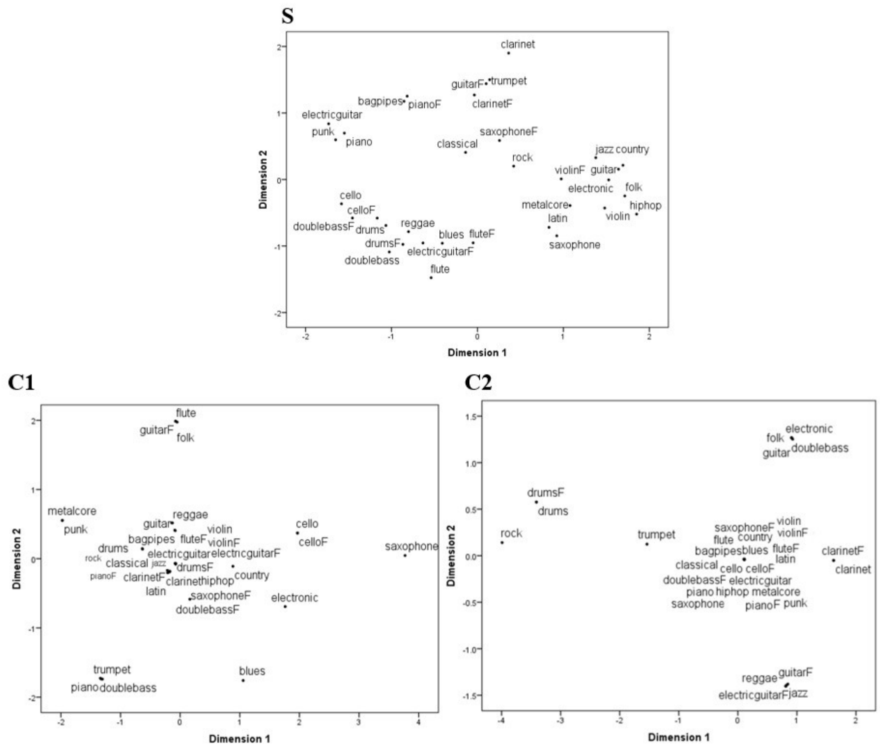

Figure 1. Two-dimensional MDS of musical stimuli based on odor associations for synaesthete S (stress = .195, RSQ = .794), and control participants C1 (stress = .157, RSQ = .932), and C2 (stress = .096, RSQ = .982). Musical instruments were played at normal speed (e.g., cello) and fast speed (e.g., celloF).

Results

A 2-by-3 repeated measures ANOVA with group (control, synaesthete) and sound (identical, instrument, random) as within-participants factors revealed a main effect of group, with odor associations from S rated more similar overall than associations from controls $F(1, 29) = 43.10$, $p < .001$, $\eta_p^2 = .598$. There was also a main effect of sound $F(2, 58) = 119.69$, $p < .001$, $\eta_p^2 = .805$. Pairwise contrasts showed—as predicted—descriptions from identical sound pairs and same instrument pairs were rated as more similar than random pairs, $F(1, 29) = 140.66$, $p < .001$, $\eta_p^2 = .829$; $F(1, 29) = 133.38$, $p < .001$, $\eta_p^2 = .821$. However, there was no difference between identical sound pairs and same instrument sound pairs, $F(1, 29) = 1.75$, $=.20$, $\eta_p^2 = .057$. There was no interaction between group and condition $F(2, 58) = .84$, $p = .44$, $\eta_p^2 = .08$, suggesting S's associations across sounds were just as consistent as controls. In order to investigate our predictions further, pairwise comparisons between each condition were conducted separately by group. For controls, same instrument pairs and identical pairs were judged more similar than random pairs (ps < .001), but there was no difference between identical pairs and same instruments pairs ($p = .15$). The same pattern was true for S, with both same instrument and identical pairs were judged more similar than random pairs (ps < .001), but no significant difference between instrument and identical pairs ($p = .79$). This suggests S's music-odor associations are driven by music timbre or instrument, rather than say tempo, since speed did not affect consistency of associations.

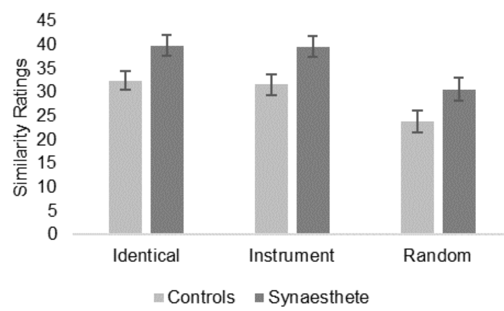

Figure 2: Mean similarity ratings from identical pairs, same instrument pairs and random pairs. Error bars reflect 1 *SE*.

Odor cognition in music-odor synaesthesia

Does having synaesthetic associations with odor improve odor cognition? As part of an investigation into another form of synaesthesia (odor-color synaesthesia, reported in Speed & Majid, 2018), S took part in a number of tasks assessing odor cognition. Here we report comparisons between S and a set of controls.[1]

Method

[1] Speed & Majid (2018) compared S with controls as part of a group. Here we used adjusted *t*-tests to compare S as an individual to controls.

Participants S was compared to 17 controls (all female, M_{age}=39.76, *SD*=13.04) who did not have any form of synaesthesia.

Material To assess odor perception, Burghart's odor discrimination and threshold tests were administered (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997). Each test contains 16 triplets of odors, presented in Sniffin' Stick pens. To investigate mental imagery of odors, we administered the Vividness of Olfactory Imagery Questionnaire (VOIQ: Gilbert, Crouch, & Kemp, 1998). The questionnaire consists of 16 descriptions of odors for which participants were instructed to imagine, e.g., "*The smell of your shirt or blouse when you remove it*". Participants also completed a questionnaire assessing the importance of olfaction in everyday life (Croy, Buschhüter, Seo, Negoias, & Hummel, 2010). The questionnaire contained 20 statements related to smell; e.g., "*Without my sense of smell, life would be worthless*". The questionnaire assessed three aspects of odor significance: (1) *the association scale* reflects the "emotions, memories and evaluations that are triggered by the sense of smell"; (2) *the application scale* reflects how much an individual uses their sense of smell every day, and (3) *the consequence scale* reflects the conclusions an individual draws from their odor experiences.

Procedure Testing took place over two separate days with a one day break in between. During the odor threshold and discrimination tests participants were blindfolded. For the odor threshold test, participants were presented triplets of odors, one of which contained variable concentrations of *n*-butanol, and two with an odorless solvent. Participants indicated which pen had the odor. Odor threshold was determined using a staircase procedure. For the odor discrimination test, participants were presented with triplets of odors, two of which contained the same odor. Participants indicated which pen smelled different. Total number of correct trials was calculated out of 16.

For the VOIQ, participants were instructed to carefully read each description and rate the vividness of the mental image from 1, "perfectly clear and vivid as normal vision" to 5 "No image at all (only "knowing" that you are thinking of the object)". Participants wrote their response in a box next to each description. An average score across questions was calculated.

The importance of olfaction questionnaire was administered on the second day of testing. Participants were instructed to read each statement carefully and respond how much they agreed using the following options: "totally agree", "mostly agree", "mostly disagree", or "totally disagree". Participants placed a cross in the box corresponding to their choice. Responses were converted to scores from 4 for "totally agree" to 1 for "totally disagree". Responses were then summed for each subscale separately (maximum 24).

Results

Scores from control participants were compared with S using adjusted *t*-tests (Crawford & Howell, 1998; Table 1 displays means). S was better able to discriminate between odors than control participants, t = 2.09, p = .05, but odor thresholds did not differ t = .76, p = .46. There was no difference between S and controls in vividness of olfactory imagery t = .89, p = .39, although numerically S reported greater vividness. However, S differed from controls in rated importance of odors. She scored significantly higher on the association scale, t = 2.01, p = .03 (one-tailed), but there were no significant differences on the application or consequence scales (although there was a trend for S to score higher overall). So, odors are more likely to trigger associations endowed with emotion, memory and evaluations for S than control participants.

Table 1. Mean and *SE* (in brackets) for odor tasks.

	S	Controls
Odor discrimination	16	11.71 (0.48)
Odor threshold	9.5	6.59 (0.90)
Odor imagery	1.81	2.69 (0.23)
Odor significance: Application	22	16.24 (0.94)
Odor significance: Association	24	18.12 (0.69)
Odor significance: Consequence	22	18.41 (0.69)

General Discussion

We have presented a case of music-odor synaesthesia—a form of synaesthesia not previously reported to our knowledge. This is important evidence that olfactory representations can be automatically activated in the absence of real odor, a feat thought to be difficult (Speed & Majid, in press). Our study also discovered music-odor associations in non-synaesthetes too, in line with previous findings (e.g., Crisinel & Spence, 2012; Levitan et al., 2015). Although there were crucial qualitative differences between S's odor associations and those of controls—S's associations were experienced automatically and vividly, whereas the controls' associations required explicit consideration—controls still showed consistency over time. Similarly, elsewhere it has been shown that music-color associations in non-synaesthetes exhibit similar mappings as those experienced in synaesthetes, such as between pitch and lightness (Ward, Huckstep, & Tsanikos, 2006). What gives rise to these associations between music and odors? Although our study did not directly address mechanisms, our findings are more consistent with some proposals.

There are several different accounts for explaining synaesthesia: synaesthesia could arise from cross-activation of perceptual regions in the brain resulting from reduced synaptic pruning during brain development (e.g., Ramachandran & Hubbard, 2001), or through disinhibited feedback between brain regions (e.g., Grossenbacher & Lovelace, 2001). There are also proposals that such associations might be semantically-mediated (e.g., Chiou & Rich, 2014; Meier, 2014). Similarly, associations across the senses for the general population have been well-documented (Marks, 1978; Spence, 2011); and are thought to arise from either innate structural connections, statistical co-occurrences in the environment, or through language (Spence, 2011).

For this type of synaesthesia, and for the music-odor associations found among the non-synaesthetes, it seems semantically-mediated accounts are less plausible. Music is a complex inducer that varies in many ways: e.g., pitch, timbre, tempo. It is unclear how semantic activation of music—unlike, say, letters or words—could explain these results. What specific meaning would associate reggae music with the odor of honey or bagpipes with the odor of metal? Similarly, music and odor do not occur together systematically; and, music is not typically described in terms of odor (aside from perfumers' descriptions cited in the Introduction). This would suggest that—as proposed for synaesthesia—music-odor associations arise from innate structures of the brain (see Deroy, Crisinel, & Spence, 2013). This is in line with the idea of a synaesthetic continuum, where the general population are considered "weak synaesthetes" (Martino & Marks, 2001; but see Deroy & Spence, 2013). Future investigations of music-odor synaesthesia could systematically manipulate features of music samples, such as pitch, in order to reveal which specific features trigger particular odors. A similar line of work, for example, revealed lexical-gustatory associations in synaesthete JIW were sensitive to sound-symbolic features of the inducing words (Bankieris & Simner, 2014).

Another possibility is that music-odor associations in synaesthesia and the general population are mediated by emotion. Music (e.g., Blood & Zatorre, 2001) and odor (e.g., Yeshurun & Sobel, 2010) are closely linked to emotion, and odor and emotion are closely connected in the brain (Soudry, Lemogne, Malinvaud, Consoli, & Bonfils, 2011), so it is a likely dimension on which associations could arise. Levitan et al. (2015) asked participants to rate music-odor matches, and separately rate the music and odors on a number of dimensional scales. They found that music-odor pairs were rated more similar when the music and odor received similar emotion ratings. This parallels the finding that music-color associations in non-synaesthetes are strongly mediated by emotion (Palmer, Schloss, Xu, & Prado-Leon, 2013; Palmer et al., 2016). To what extent emotion is involved in music-odor synaesthesia remains unclear, however, it would be in line with proposals for a role of anatomical proximity in synaesthesia, where it has been suggested that proximity of brain regions would lead to cross-activation of those regions (e.g., Ramachandran & Hubabrd, 2001; Ward, Simner, & Auyeung, 2005)

The present study sheds light on an understudied form of synaesthesia. In addition, the existence of synaesthesia with odor as the concurrent modality has important implications for general theories of odor cognition. Against the supposition of weak odor representations (Cain, 1979; Crowder & Schab, 1995; Olofsson & Gottfried, 2015; Speed & Majid, in press), music-odor synaesthesia is an intriguing phenomenon where apparently olfactory information can be activated without the presence of odor stimuli. S could easily describe her odor associations, in line with the proposal that limitations of odor language can be overcome with the right sorts of experience (e.g., Croijmans & Majid, 2016; Majid & Burenhult, 2014; O'Meara & Majid, 2016; Speed & Majid, 2018; Wnuk & Majid, 2014). S can also better discriminate odors, and has stronger associations with odor, supporting the proposal that olfaction is not as limited as often thought (see also Majid, Speed, Croijmans, & Arshamian, 2017; Speed & Majid, 2018).

Our study presents an individual with music-odor synaesthesia for the first time. Future work is needed to establish the automaticity and long-term consistency of these synaesthetic music-odor associations. We also highlight crossmodal associations between music and odor in non-synaesthetes. Music may not be invisible, as Auden proposed, but instead becomes more discernable through its multimodal perceptual associations.

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