BRILL *Multisensory Research (2026)* DOI:10.1163/22134808-bja10200 brill.com/msr

Seeing Scent in Sound: Exploratory Spontaneous Visual and Olfactory Mental Imagery Elicited by Musical Modes

Oriente Pimentel Aldaz * **and Charles Spence**

Crossmodal Research Laboratory, Life & Mind Building, University of Oxford, Oxford OX1 3EL, UK

*Corresponding author; e-mail: oriente.pimentelaldaz@psy.ox.ac.uk

ORCID iDs: Pimentel Aldaz: 0009-0007-9020-9738; Spence: 0000-0003-2111-072X

Received 19 February 2026; accepted 20 May 2026; published online 10 June 2026

Abstract

Musical modes (i.e., different patterns of pitch organisation within a scale) are widely recognised for their emotional character, yet little is known about the broader multisensory associations that listening to them might trigger. In the present exploratory study, we examine whether the full set of Western musical modes elicits systematic patterns of visual and olfactory mental imagery and whether these patterns correspond with how listeners spontaneously group the modes. In all, 249 participants generated open-ended visual and olfactory responses while listening to short modal excerpts and subsequently completed a free-sorting task. The results revealed a number of structured and recurrent imagery themes across participants (e.g., Nature-, Daytime-, and Happiness-related imagery for major modes, *versus* Dark-, Stress- and Sadness-related imagery for minor modes, alongside Floral-and-Fresh- *versus* Damp-, Dusty- and Smoke-related olfactory associations). Major and minor modes occupied distinct regions of similarity space across both visual and olfactory modalities; however, meaningful differentiation was also evident at the level of individual modes. This consistent relational structure across visual and olfactory imagery was likewise reflected in the grouping patterns observed in the free-sorting task. Together, these findings indicate that musical modes are associated with multiple sensory representations that extend beyond simple feature-level correspondences. These results therefore provide an exploratory mapping of visual and olfactory mental imagery and establish a foundation for future confirmatory research.

Keywords

crossmodal correspondences, mental imagery, musical modes, smell, sound, visual

Published with license by Koninklijke Brill BV | DOI: 10.1163/22134808-bja10200

1. Introduction

Humans do not experience the senses in isolation. Sounds are described as ‘Bright’ or ‘Dark’, scents as ‘Fresh’ or ‘Warm’ and flavours as ‘Sharp’. Music itself may be perceived as ‘Heavy’, ‘Sweet’, or ‘Spicy’. Such cross-sensory associations reflect a long-recognised unity amongst the senses (Marks, 1978; von Hornbostel, 1950) and the tendency for features in one sensory domain to be reliably linked with features in another. A substantial body of contemporary research focuses on studying crossmodal correspondences, defined as the systematic associations between features across different sensory domains widely shared across the general population (see Spence, 2011, for a review). They have now been documented across a wide range of different sensory pairings, including vision–audition, audition–olfaction, vision–touch, taste–smell, and even more abstract (and possibly non-sensory) dimensions such as temporal duration and spatial elevation (Evans and Treisman, 2010; Parise *et al.*, 2014; Stevenson *et al.*, 2012; Vainio *et al.*, 2025; Walker and Walker, 2012).

Spence (2011) identified a non-exclusive taxonomy of mechanisms by which crossmodal correspondences may arise: physiological (or structural), statistical, semantic, and affective. Physiological correspondences reflect shared neural or psychophysical coding across different sensory modalities, often rooted in innate or early-developing biological processes (Di Stefano and Spence, 2024; Stevens, 1957). Statistical correspondences are learned through repeated exposure to patterns of environmental regularities, as when two sensory features commonly co-occur (Ohtake *et al.*, 2023). For example, the pitch–size correspondence may result from the fact that smaller objects physically tend to produce higher-pitch sounds, leading to a learned association of high pitch with smaller concepts (Gallace and Spence, 2006; Motoki *et al.*, 2023). Semantic correspondences are thought to depend on overlapping linguistic or conceptual labels; for example, matching a round shape to a sweet taste because both are evaluated similarly along shared semantic dimensions such as pleasantness and intensity (Spence, 2023; Velasco *et al.*, 2016). Lastly, affective correspondences link sensory features through their shared emotional or hedonic valence (Lim *et al.*, 2009), as seen in music–colour pairings that are consistently matched based on the shared emotional content that they convey (Palmer *et al.*, 2013; Zhou and Yamanaka, 2018; see also Spence, 2020, for a review).

1.1. Olfactory–Auditory Crossmodal Correspondences

> “Scents, like sounds, appear to influence the olfactory nerve in certain definite degrees. There is, as it were, an octave of odours like an octave in music; certain odours coincide, like the keys of an instrument.”
>
> G. W. Septimus Piesse, *The Art of Perfumery* (1867)

The study of olfactory–auditory crossmodal correspondences has evolved from early investigations using simple, isolated stimuli (e.g., matching individual odorants to pitches) to more recent work involving more complex and structured auditory and olfactory stimuli (Spence *et al.*, 2026). The idea that sounds and smells might be organised analogously is hardly new. In the late 1800s, Septimus Piesse proposed his 'Gamut of Odours', drawing parallels between fragrance blending and musical harmony, suggesting that odour components might combine according to similar principles to musical notes.

While largely speculative, Piesse's (1867) suggestions have inspired multiple subsequent researchers (and artists) often involving experiments that demonstrate systematic associations between single odorants (or rather, odours that are perceived as unitary) and specific pitches: For instance, participants have been shown to consistently match citrus-type aromas with high pitches and musk-type aromas with low pitches (Belkin *et al.*, 1997; Crisinel and Spence, 2012). More recent research on timbre–aroma crossmodal correspondences has revealed that fruity and sour scents are typically linked to bright timbres and strong harmonic energy, whereas spicy or woody aromas tend to be matched with rougher timbres (Zacharakis, 2024). These associations are also mediated by shared semantic descriptors such as 'bright', 'warm', or 'fresh', with multidimensional scaling (MDS) analyses showing convergent semantic structures across the senses (Zacharakis, 2025).

1.2. Musical Modes as Mid-Level Auditory Stimuli

Recent studies in crossmodal correspondence research have moved beyond matching isolated, basic features and now investigate dynamic, midlevel auditory constructs that typically emerge from sequences or combinations of simpler elements (see Spence and Di Stefano, 2026, for a review). Within this framework, it has recently been suggested that crossmodal correspondences can be organised into a tripartite hierarchy of simple (or unitary), midlevel, and complex levels that are defined by the perceived internal structure and complexity of the stimuli involved (see Table 1). Midlevel correspondences, in particular, involve temporally and/or spatially patterned stimuli, where the mapping depends on the relational structure of changes over time or space (e.g., melodic contours, rhythmic groupings, tempo gradients, or other spatiotemporal trajectories), rather than on single, isolated features (e.g., Sepehr *et al.*, 1988; Starr and Srinivasan, 2018). By contrast, simple correspondences link perceptually unitary sensory features such as pitch height, loudness, hue, or brightness. Complex correspondences involve multidimensional, semantically rich stimuli such as musical excerpts, film clips, or artworks in which multiple features and relations are integrated and not easily decomposed without a loss of identity. The increase in the complexity of the stimuli enables researchers to examine analogical or structural mappings between temporally

Table 1.
Levels of crossmodal correspondence according to stimulus complexity

Level	Description	Examples		
		Auditory	Olfactory	Visual
Simple (unitary)	Perceptually simple, individual sensory features or attributes	Pure tone; pitch height; loudness; single timbre; isolated harmonic interval	Perceptually unitary odorant (e.g., vanillin); intensity of a scent	Colour patch; brightness; hue; simple geometric shapes
Midlevel	Combination or sequential organisation of multiple basic elements	Musical mode; melodic contour; rhythmic pattern; tonal stability; interval sequence	Binary odour mixture; blended accord	Dynamic stimuli; colour harmony; patterned textures
Complex (high-level)	Multidimensional, often semantically meaningful stimuli that integrate multiple features and relations and cannot be easily decomposed without loss of identity	Musical excerpt; film score; genre	Full fragrance composition; ambient smells	Painting; film clip; multimedia scene

The table summarises the distinction between simple (unitary), midlevel, and complex crossmodal correspondences as described by Spence and Di Stefano (2025). Examples are provided across auditory, olfactory, and visual modalities to illustrate how stimulus complexity varies.

or spatially patterned stimuli (e.g., a sequence of tones or changing musical mode) and corresponding structures in other modalities, revealing crossmodal associations that reflect more than low-level sensory similarity (Spence and Di Stefano, 2026).

Research exploring crossmodal mappings has begun to incorporate musical modes as a midlevel class of auditory stimuli. In Western music, musical modes (ordered series of intervals that define distinct pitch organisations within a scale) encode unique patterns of melodic, harmonic, and affective qualities. Modes can be understood as different ways of organising the same set of notes in order to produce distinct tonal qualities or moods (e.g., major modes sounding brighter, minor modes darker).

While the Ionian and Aeolian modes are commonly associated with major and minor tonalities, respectively, and have been the primary focus of research due to their prevalence in classical and popular repertoires, the full set of diatonic modes (Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian and

Locrian) each convey distinctive characteristics linked to their intervallic structure (Straehley and Loebach, 2014). Listeners report robust affective associations: major modes are perceived as brighter and happier, like Lydian and Mixolydian which tend to evoke energy and openness. Minor modes are perceived as darker and sadder, while Phrygian, for example, often conveys tension (Chang, 2025; Collier and Hubbard, 2004; Pimentel *et al.*, 2025; Ramos *et al.*, 2011). At a more basic structural level, recent research has demonstrated that isolated harmonic intervals differing in consonance and dissonance reliably evoke distinct emotional associations, with more dissonant intervals linked to sadness and tension, and more consonant intervals associated with happiness and hopefulness, suggesting that interval-level acoustic properties may contribute to the broader affective character of modal systems (Pillay *et al.*, data not shown).

Studies consistently demonstrate that modal structure and tonal context shape multisensory mappings across both the olfactory and visual domains. For instance, findings reveal robust mode-to-colour mappings: tonally stable, major-like contexts (whether formed by scales, chords, or timbre) consistently elicit brighter, more saturated colours, while minor, unstable, or dark timbres evoke darker, less saturated hues (Harashima *et al.*, 2025; Maimon *et al.*, 2020; Palmer *et al.*, 2016; Reymore and Lindsey, 2025). Beyond olfaction, auditory–gustatory crossmodal correspondence research has revealed related patterns, with different modes and chords evoking distinct taste (i.e., gustatory) associations, modulated further by listeners' culinary experience (Ozilgen, 2021; Taitz *et al.*, 2019).

1.3. Crossmodal Mental Imagery

Beyond direct perception, this investigation involves examining internal sensory experiences even when a stimulus in the target sense is entirely absent. Crossmodal mental imagery, defined as perceptual processing within one sensory modality that is elicited by stimulation in another sensory modality, in the absence of the corresponding physical input (Lacey and Lawson, 2013; Spence and Deroy, 2013), is particularly relevant for the present study. Empirical work shows that mental imagery and actual perception share numerous similarities and frequently interact (Spence, 2024). For instance, a sweet tastant and the word 'sweet' are both associated with round (*vs* angular) shapes (Velasco *et al.*, 2015), and both imagined and actually experienced cold water are associated with higher-pitch and faster-tempo auditory stimuli (Wang and Spence, 2017). Focusing specifically on scent imagery, the perception and imagery of scents have been shown to share significant overlap in terms of the brain regions that are involved (Gottfried and Zald, 2005; Spence, 2022), with olfactory mental imagery engaging similar perceptual processing pathways as the actual exposure to scent (Arshamian and Larsson, 2014). Converging neuroimaging evidence further suggests that mental imagery engages both modality-specific and shared neural mechanisms. For instance, regions such as the Supplementary Motor Area (SMA) have been implicated in imagery across both olfactory and auditory domains, albeit with modality-dependent patterns of engagement (Leclerc *et al.*, 2019). Hossu *et al.* (2024) recently demonstrated that visual stimuli can reliably trigger odour imagery and activate the olfactory network in the human brain. However, this study did not report activation in primary olfactory regions (e.g., piriform cortex), a finding that contrasts with several previous neuroimaging studies (e.g., Djordjevic *et al.*, 2005; Flohr *et al.*, 2014).

1.4. Research Gaps

Despite considerable progress having been made in mapping crossmodal correspondences between the auditory, olfactory, and visual domains, several important empirical gaps in the literature still remain. First, research on musical mode has been largely restricted to the major–minor dichotomy, often reducing modal perception to a single affective axis. This oversimplification leaves the full set of diatonic modes almost entirely unexplored with respect to their broader crossmodal associations.

Second, much of the existing literature relies on forced-choice matching tasks or rating scales that presuppose the relevant dimensions of correspondence (e.g., brightness, pleasantness, intensity). While such paradigms are well-suited for confirmatory testing, they may obscure how participants naturally tend to organise and describe structurally complex auditory stimuli such as musical modes.

Finally, midlevel crossmodal correspondences involving structured auditory stimuli such as melodic patterns or tonal systems, represent a relatively recent area of empirical investigation (Spence and Di Stefano, 2026). Although basic feature mappings (e.g., pitch–brightness) are well documented, comparatively little is known about how such midlevel auditory constructs operate across the senses. In particular, it remains unclear whether musical modes evoke coherent multisensory representations that extend beyond isolated feature correspondences.

Addressing these gaps in the literature requires an exploratory approach that allows crossmodal associations and perceptual organisation to emerge from participants' spontaneous responses rather than from predefined categories or dimensions.

1.5. The Present Study

Building on the latest research on crossmodal correspondences, the present exploratory study investigated whether musical modes, treated as midlevel auditory structures, elicit coherent and systematically organised multisensory associations in the absence of any concurrent stimulation in other sensory modalities. Rather than restricting responses to predefined dimensions or forced-choice mappings, the participants in the present study were invited to generate open-ended visual and olfactory mental imagery while listening to excerpts representing each of the seven Western diatonic modes.

In addition to these imagery reports, participants completed a free-sorting task in which they grouped the musical modes according to their own perceptual or conceptual criteria, without predefined categories or response dimensions. This combination of tasks was designed to capture both the semantic content of participants' multisensory associations and the implicit perceptual organisation underlying their judgements.

The study adopted an integrative analytic approach combining qualitative thematic analysis with quantitative modelling of free-sorting behaviour. This enabled the identification of emergent semantic themes associated within each mode alongside perceptual structures reflecting participants' spontaneous organisation of the stimuli. By examining the convergence between imagery-derived themes and perceptual similarity structures, the study aimed to assess whether musical modes evoke stable and shared multisensory representations rather than idiosyncratic or purely affective associations.

Importantly, the present study does not seek to establish fixed or deterministic crossmodal correspondences between musical modes and specific olfactory stimuli or visual scenes. Instead, the goal is to provide a systematic mapping of the mental imagery landscapes and organisational principles associated with diatonic modes, thereby establishing an empirical foundation for subsequent confirmatory investigations.

2. Methodology

2.1. Participants

An *a priori* power analysis using G*Power 3.1 (Faul *et al.*, 2007) with $w = 0.30$, $\alpha = 0.05$, power $= 0.95$, and six degrees of freedom indicated a required sample size of 232 participants to detect medium-sized effects in χ^2 contingency analyses. To allow for potential exclusions, 250 participants were recruited *via* Prolific Academic (https://app.prolific.com/) in exchange for monetary compensation at a rate of £9 per hour (pro rata). All of the participants were based in the United Kingdom, were fluent English speakers, and reported normal auditory and olfactory functioning. Pregnant women were excluded from the study due to documented shifts in olfactory sensitivity and hedonic perception (Agbor Epse Muluh *et al.*, 2024). One participant was excluded prior to analysis due to incomplete responses, resulting in a final sample of 249 participants.

The final sample had a mean age of 36.4 years (SD = 7.94), with ages ranging from 19 to 50 years of age.[1] The sample was predominantly female (245 female participants, three male participants, and one participant identifying as non-binary or third gender). With respect to musical background, the majority of participants (81.1%) reported no formal musical training beyond general primary or secondary education. A smaller proportion reported elementary musical education (10.8%), while 6.8% reported holding a bachelor's, postgraduate, master's, or doctoral degree in music. A very small subset of participants (1.2%) reported professional musical education at the conservatory level. The study was approved by the Central University Research Ethics Committee of the University of Oxford (R90531/RE003).

2.2. *Materials and Stimuli*

Seven audio excerpts were created, each exemplifying a single diatonic mode (Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian and Locrian). All excerpts were constructed using an identical musical skeleton: a homophonic texture presenting a single, prominent melody over a harmonic accompaniment. To isolate modal structure from potential confounds introduced by key signatures or accidentals (sharps or flats), all seven modes were presented in the C-major configuration (i.e., using only the white keys on the piano). This approach ensures that each mode derives from an identical pitch set (C, D, E, F, G, A, B), with each mode differing solely in its intervallic function and tonal centre (Ramos *et al.*, 2011). This C-major layout enhances listener familiarity, minimising potential biases linked to uncommon key signatures and was designed to maintain the participants' focus on the modal pitch relationships (Straehley and Loebach, 2014).

An original melody was composed to reduce any familiarity, rote memory, or associations from known musical pieces (Sauvé *et al.*, 2024). The consistent use of the piano throughout all seven excerpts, coupled with identical melodic and harmonic content across modes, provided experimental control of both pitch and timbre. This midlevel stimulus design was intended to maximise perceptual distinctiveness between modes while maintaining a high degree of structural comparability. Each audio excerpt was standardised to a duration of 25 s, set at 90 beats per minute. Audio files were delivered *via* the experimental survey platform (Qualtrics) and embedded directly within the experimental sequence. The sound stimuli are available online at Open Science Framework.

[1] Participants' age restriction was set to minimise age-related variability in auditory and olfactory perception, as identification abilities have been documented to decline after the fifth decade of life (Britt *et al.*, 2025; Doty *et al.*, 1984; Wasano *et al.*, 2022; Wood and Harkins, 1987). This constraint increases internal validity while retaining a broad adult sample.

Figure 1. The seven musical excerpts (Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian, and Locrian) derived from an identical melodic and harmonic framework using the same pitch collection, differing only in their tonal centre and resulting intervallic structure.

2.3. Procedure

The study was conducted online and programmed using Qualtrics survey software (https://www.qualtrics.com/). The participants were instructed to complete the experiment while wearing headphones in a quiet, undisturbed environment in order to minimise any auditory distraction. After providing their informed consent, the participants completed an inclusion screening and an audio attention check to confirm adequate sound playback and equipment functionality. Demographic information was then collected, including age, gender, and self-reported musical background.

Participants listened to seven musical excerpts, each exemplifying a different diatonic mode. The order of the excerpts was randomised across participants. For each excerpt, the participants were first instructed to respond with whichever association came to mind most readily, choosing whether to begin with an olfactory or a visual response. They then completed both open-ended prompts in turn: “What kind of smell would you associate with this particular music excerpt?” and “Describe the visual scene or mental imagery that comes to mind when listening to this excerpt.” Participants were permitted to replay each excerpt as many times as necessary before providing their responses. An attention check was embedded at a random point within the sequence of musical excerpts to assess attentive listening.

After completing the mental imagery tasks for all seven musical modes, the participants completed a free-sorting task in which they were asked to organise the seven musical excerpts into groups according to their own criteria, creating as many or as few groups as they felt were appropriate. Following the sorting task, participants were invited to briefly describe the rationale underlying their groupings, indicating what made the sounds within each group seem similar or related. The entire procedure had a median completion time of 13 min.

2.4. Analyses

All analyses were conducted within the R environment for statistical computing (version 4.5.1; R Core Team, 2025). The analyses were designed to characterise the semantic structure of olfactory and visual imagery evoked by musical modes, to model perceptual similarity between modes, and to evaluate any correspondence between imagery-based and sorting-based representations.

Open-ended olfactory and visual imagery responses were analysed using an inductive thematic analysis (Braun and Clarke, 2006) supported by a large language model (LLM), following recent methodological work on LLM-assisted qualitative analysis (De Paoli, 2024; Khalid and Witmer, 2025). Text responses were minimally preprocessed to remove empty or malformed entries while preserving original wording and linguistic structure; no stopword removal, lemmatisation, or stemming was applied. Responses indicating imagery difficulty, neutrality, or minimal sensory content were retained, as these constituted meaningful experiential information. Initial inductive coding was performed using a single fixed prompt applied uniformly across responses with the gpt-4.1-mini model (temperature = 0), accessed *via* the OpenAI API, which enabled the consistent and reproducible application of a fixed coding prompt across all responses. For each response, the model generated a concise code label, a brief description, and a verbatim supporting quote. Use of the LLM was restricted to this initial coding stage. All subsequent consolidation, refinement, and interpretation of codes were conducted manually by the researchers.

Canonical theme labels were assigned through iterative human review, with semantically overlapping codes merged and compound responses split where necessary. Theme frequencies were summarised by musical mode and converted to within-mode proportions to characterise the relative composition of imagery associated with each mode. To avoid inflated counts arising from repeated annotations, analyses were repeated on deduplicated datasets retaining unique participant × mode × theme combinations. Complementary normalisation was also applied by computing percentages within theme, allowing assessment of how individual imagery themes were distributed across modes.

To identify imagery themes that were both prevalent within a musical mode and relatively specific to that mode, a term frequency–inverse document frequency (TF–IDF) weighting procedure was applied (Salton and Buckley, 1988). Term frequency (TF) was defined as the proportion of responses within each mode assigned to a given theme. Inverse document frequency (IDF) was computed as $\log(N/(1+n_i))+1$, where N represents the total number of modes (7) and n_i the number of modes in which a given theme occurred. The addition of 1 in the denominator provides smoothing to avoid division by zero. Final TF–IDF weights were computed as TF $\times$ IDF.

Term frequency–inverse document frequency-weighted mode $\times$ theme matrices were analysed using cosine distance (defined as 1-cosine similarity) to quantify similarity between musical modes, followed by hierarchical clustering with average linkage and classic MDS to visualise low-dimensional structure (Kruskal and Wish, 1978). For classical MDS, the proportion of variance explained by the first two dimensions was calculated as the sum of the first two positive eigenvalues divided by the sum of all positive eigenvalues. Convergence between visual and olfactory imagery structures was assessed by computing the Spearman correlation between the pairwise cosine distance matrices derived independently from each modality. Statistical significance of matrix correspondence was evaluated using a Mantel permutation test (Mantel, 1967).

Free-sorting responses were converted into pairwise co-occurrence counts between musical modes. Participants who placed all seven modes into a single group ($N = 4$) were excluded from the sorting analyses. For the remaining data, each participant group was expanded into unordered mode pairs, and co-occurrence proportions were calculated as the number of participant groups containing both modes divided by the total number of participant groups (677). Dissimilarities were defined as distance = 1-proportion and analysed using classical MDS and hierarchical clustering.

Free-sorting rationales (open-ended reasons for grouping) were analysed using the same inductive thematic pipeline described above, combining automated LLM-assisted coding with subsequent human validation. Coding was performed *via* the OpenAI API. Canonical themes were then tabulated by musical mode, deduplicated at the participant $\times$ mode $\times$ theme level, converted to within-mode percentages, and visualised using ggplot2. Batching procedures, retry logic, and metadata logging were employed to support reproducibility.

Analyses were implemented using base R and tidyverse packages, with string similarity computed using stringdist, distance-based analyses using vegan and proxy, and visualisations generated using ggplot2. The data set, codebooks and materials required for the evaluation and reproduction of the results have been made publicly available online at Open Science Framework.

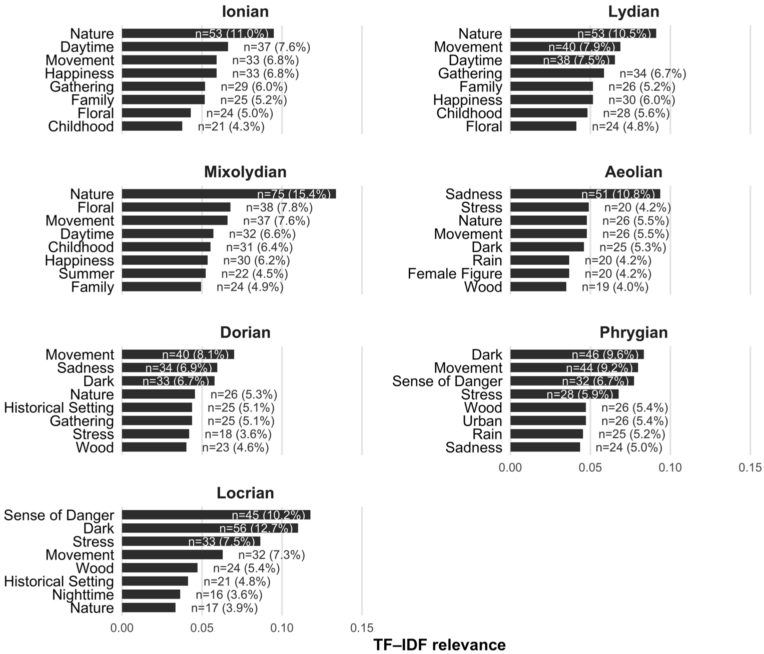

Figure 2. Mode-specific visual mental imagery themes (term frequency–inverse document frequency (TF–IDF)). Bars show the eight highest TF–IDF visual themes for each musical mode. TF–IDF weights combine within-mode prevalence and across-mode specificity to emphasise themes that are both common within a given mode and relatively distinctive across modes. Labels to the right of each bar report the raw count (*n*) and the percentage of that mode's visual imagery responses assigned to the theme.

3. Results

3.1. *Visual Mental Imagery Themes*

Visual imagery contributions were broadly comparable across modes (460–525 per mode), with a relatively narrow and overlapping range of distinct visual themes observed across modes (approximately 41–46 per mode).

The mode-specific prominence of visual imagery themes is summarised in Fig. 1, which presents the eight highest-ranking visual themes per musical mode based on TF–IDF weighting. Full descriptive counts and percentages for all visual themes are provided in the Appendix (Table A1).

Inspection of the TF–IDF rankings revealed distinct mode-specific visual imagery profiles, which differed systematically between modes traditionally classified as major (Ionian, Lydian, Mixolydian) and minor (Aeolian, Dorian, Phrygian, Locrian). Across all three major modes, Nature emerged as the highest-ranking visual imagery theme. This pattern was especially pronounced for Mixolydian. In addition to Nature, scene-based themes such as Daytime, Family, and Childhood ranked highly across all major modes, alongside the affective theme Happiness.

Ionian and Lydian exhibited highly similar TF–IDF profiles, with overlapping sets of top-ranked themes and comparable relative weightings. Mixolydian, while sharing the dominant Nature and Daytime themes, showed a distinct profile characterised by a higher-ranking Floral theme relative to Ionian and Lydian, as well as the appearance of Summery imagery among its top-ranked themes.

In contrast, the minor modes showed greater differentiation among themselves. Themes related to Dark, Stress, and Wood appeared consistently among the higher-ranking visual imagery themes across all minor modes. Aeolian and Dorian were characterised by particularly high TF–IDF rankings for Sadness, with Dorian also showing Historical Setting imagery among its more prominent themes. Phrygian and Locrian, by contrast, were distinguished by elevated TF–IDF rankings for Sense of Danger, alongside Dark and Stress imagery. Across all of the musical modes, Movement appeared among the higher-ranking themes, although its relative prominence varied across modes.

3.2. Olfactory Mental Imagery Themes

Olfactory mental imagery contributions were broadly comparable across modes (317–349 responses per mode), with the number of distinct olfactory themes per mode varying within a limited range (approximately 37–42 per mode). Figure 2 presents the eight highest-ranking olfactory themes per musical mode based on TF–IDF weighting. Full descriptive counts and percentages for all olfactory themes are provided in the Appendix (Table A2).

Inspection of the TF–IDF rankings revealed clear mode-specific olfactory mental imagery profiles, again differing between modes traditionally classified as major and minor. Across all three major modes, Floral emerged as the highest-ranking olfactory theme. In Ionian, Woody imagery also ranked highly and was distinctive in that it did not appear among the top-ranked themes for either Lydian or Mixolydian. Lydian and Mixolydian otherwise showed overlapping sets of prominent olfactory themes, although Mixolydian was characterised by a notably higher ranking of Grass imagery relative to the other major modes.

Among the minor modes, Damp emerged as the highest-ranking olfactory theme across all four modes. In addition, Dusty, Woody, and Smoke consistently appeared among the higher-ranking olfactory themes across all minor modes. Aeolian was further characterised by the presence of Oceanic imagery among its more prominent themes. Dorian showed a distinct profile, with Earthy olfactory imagery ranking more highly than in the other minor modes. Phrygian exhibited particularly high rankings for Smoke, alongside Chemical

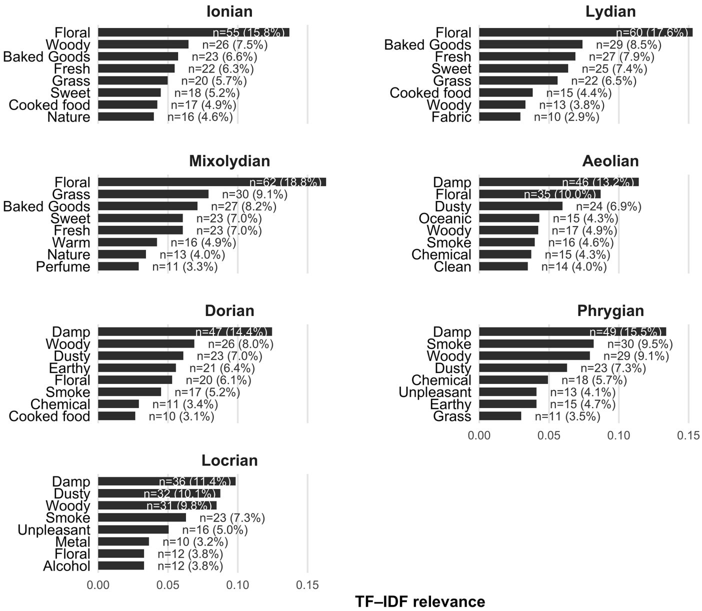

Figure 3. Mode-specific olfactory mental imagery themes (term frequency–inverse document frequency (TF–IDF)). Bars show the eight highest TF–IDF olfactory themes for each musical mode. TF–IDF weights combine within-mode prevalence and across-mode specificity to emphasise themes that are both common within a given mode and relatively distinctive across modes. Labels to the right of each bar report the raw count (n) and the percentage of that mode's olfactory imagery responses assigned to the theme.

and Unpleasant imagery, while Locrian was also distinguished by the prominence of Unpleasant imagery as well as the appearance of Metal among its higher-ranking olfactory themes.

3.3. Mode Similarity Based on Mental Imagery

Similarity between musical modes based on imagery-derived theme profiles was quantified using cosine distances between TF–IDF–weighted mode × theme vectors for visual and olfactory imagery (see Tables A3 and A4 in the Appendix). The resulting distance matrices were very highly correlated (Spearman $\rho = 0.948$), indicating a strong correspondence between visual- and olfactory-based representations of mode similarity. This correspondence was confirmed using a Mantel permutation test ($r = 0.945$, $p < 0.001$; 5039 permutations).

The structure of these similarities was then visualised in a two-dimensional MDS configuration derived from visual and olfactory imagery (Fig. 3), while the corresponding hierarchical clustering solutions for visual and olfactory imagery are shown in Fig. 4A and 4B, respectively. Sensitivity analyses

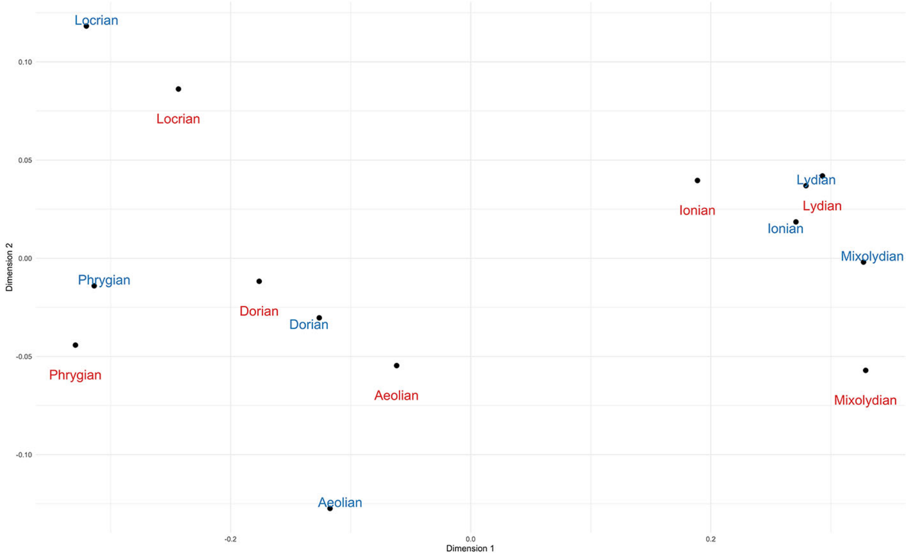

Figure 4. Multidimensional scaling (MDS) of musical modes based on mental imagery-derived similarity.. Musical modes are plotted in a shared semantic space, with labels colour-coded by modality: blue labels represent visual imagery, and red labels represent olfactory mental imagery. Distances reflect relative dissimilarity between modes. The first two dimensions explain ≈98.8% and ≈99.9% of the positive eigenvalue variance for the visual and olfactory solutions, respectively.

excluding participants with advanced or professional musical training yielded highly similar visual and olfactory imagery profiles, and the correspondence between modalities remained virtually unchanged.

Visual inspection of the two-dimensional MDS configuration reveals a structured organisation of musical modes based on imagery-derived similarity. The three major modes appear in close proximity, occupying adjacent positions within the same region of the two-dimensional space. In contrast, the minor modes are more widely distributed. Within this set, Aeolian and Dorian lie closer to the major-mode cluster, whereas Phrygian and Locrian are positioned further away. Locrian appears most separated from the other modes. This overall spatial pattern is observed in both visual and olfactory imagery MDS solutions.

Hierarchical clustering based on TF–IDF cosine distances converges with these spatial relationships. In terms of visual imagery, the major modes form a compact cluster, while the minor modes subdivide into two pairs: Dorian and Aeolian on the one hand, and Phrygian and Locrian on the other. This internal structure among minor modes is not preserved in olfactory imagery, where Aeolian emerges as relatively more distant and the remaining minor modes do not form tight subgroups. Together, the MDS and clustering results indicate

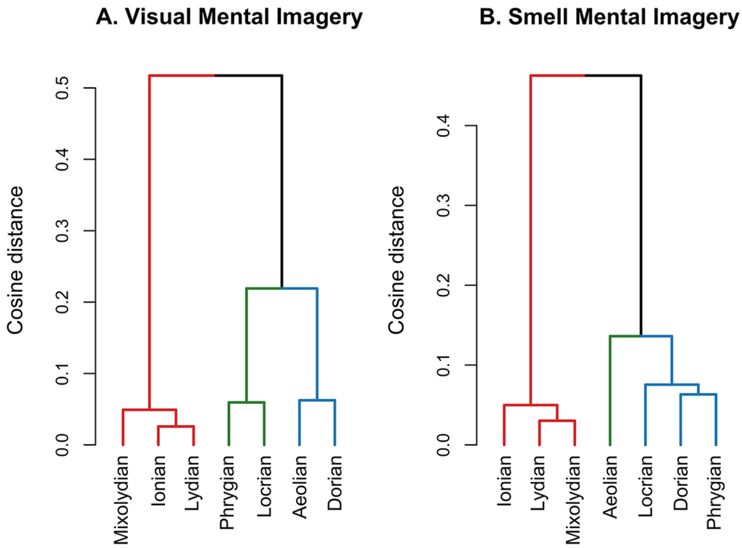

Figure 5. Hierarchical clustering of musical modes based on visual (A) and olfactory (B) mental imagery. Panels show hierarchical clustering solutions (average linkage) based on cosine distances between term frequency–inverse document frequency (TF–IDF)-weighted imagery theme profiles. (A) Clustering derived from visual imagery themes; (B) clustering derived from olfactory imagery themes. Branch height indicates relative dissimilarity between musical modes.

stable similarity among major modes across modalities, alongside modality-dependent differences in how individual minor modes are perceived.

3.4. Free-Sorting of Musical Modes

Free-sorting responses were provided by the full behavioural sample ($N =$ 249). Four participants who placed all seven modes into a single group were excluded from the sorting analyses, leaving 245 participants contributing usable sorting data. Co-occurrence proportions were computed at the participant group level (677 total groups), with each non-empty group contributing one instance of the mode pairs it contained (see Table A5 in the Appendix for full counts). The most frequent co-occurrences reflected two dominant patterns: strong pairing among major modes (e.g., Lydian–Mixolydian; Ionian–Lydian) and strong pairing among certain minor modes (e.g., Locrian–Phrygian; Dorian–Aeolian). Co-occurrence proportions were converted to distances and represented using MDS and hierarchical clustering (see Fig. 5).

Inspection of the free-sorting representations revealed a structured organisation of musical modes. In both the MDS configuration and the hierarchical

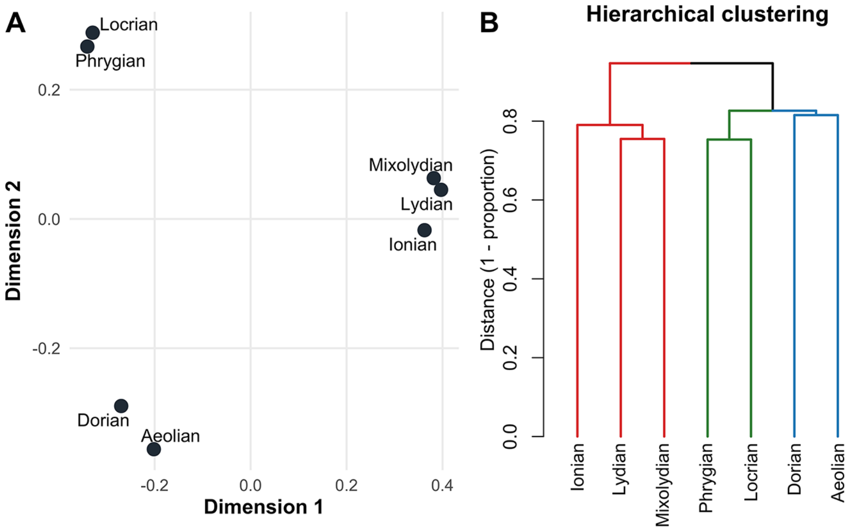

Figure 6. Free-sorting similarity of musical modes. (A) Classical multidimensional scaling (MDS) (2D) of distances derived from co-occurrence proportions (distance=1-proportion). Two dimensions explain ≈48.4% of positive eigenvalue variance. (B) Hierarchical clustering (average linkage) of the same distance matrix. Points/branches reflect relative similarity (closer = more frequently grouped).

clustering solution, modes traditionally classified as major and minor occupied largely separate regions of the space. Within the minor modes, Phrygian and Locrian were positioned apart from Dorian and Aeolian, indicating further internal differentiation among minor modes in the free-sorting data. The two-dimensional MDS solution accounted for approximately 48.4% of the positive eigenvalue variance, indicating that the first two dimensions captured a substantial but incomplete portion of the sorting structure, while the hierarchical clustering showed relatively large linkage distances between groups, reflecting variability in how consistently modes were grouped across participants. Note that sensitivity analyses excluding musically trained participants produced a nearly identical free-sorting structure, with 48.4% of the variance explained in the full sample and 48.7% after exclusion.

Free-sorting rationales summarised in Fig. 6 revealed a clear major/minor split in reported themes (see Table A6 in the Appendix for full counts and percentages for all rationale themes). The three major modes were dominated by positively valenced rationales (Happy/Positive), whereas the minor modes were dominated by negatively valenced rationales. Aeolian and Dorian were particularly notable for the high proportion of Sad/Melancholic responses, while Phrygian and Locrian showed elevated proportions of Creepy/Unsettling and Dark themes. Perceptual reasons (e.g., Similar Timbre/Texture, Pitch

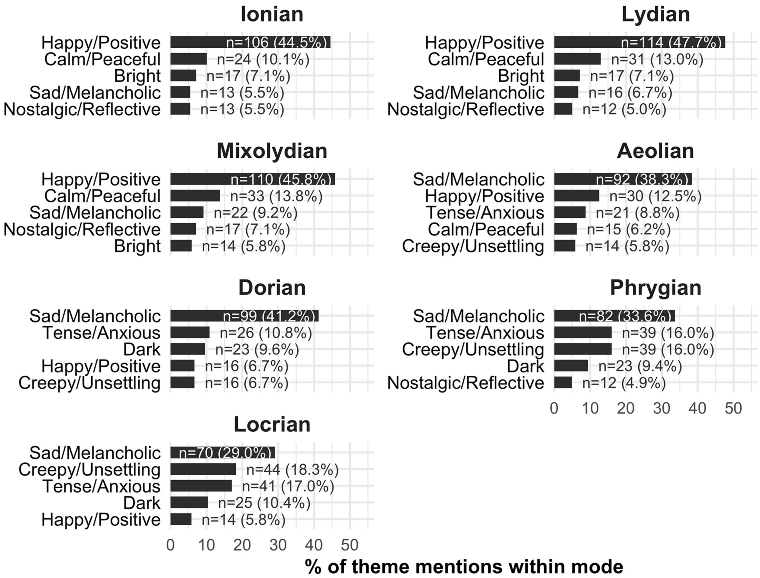

Figure 7. Top five free-sorting rationale themes by musical mode. Bars show the percentage of free-sorting rationale responses within each mode assigned to each theme; labels report raw counts (n) and percentages.

descriptors) occurred less frequently and were more evenly distributed across modes.

4. Discussion

Music has long been understood as being capable of evoking vivid scenes, moods, and even imagined sensory experiences in the absence of physical stimuli. While the emotional character of major and minor tonalities has been widely discussed, far less is known about whether, and how, the full set of Western diatonic modes is associated with visual and olfactory experiences. The present exploratory study addressed this gap in the literature by examining whether different musical modes elicit structured visual and olfactory mental imagery and whether these imagery patterns align with participants' spontaneous grouping behaviour in a free-sorting task.

The findings demonstrate that musical modes evoke coherent and systematically organised imagery rather than diffuse or idiosyncratic responses. Across both visual and olfactory modalities, modes traditionally classified as major and minor occupied distinct regions of the similarity space, while additional differentiation emerged within the minor modes. Importantly, the perceptual organisation revealed by free-sorting closely aligned with the structure derived from mental imagery, indicating convergence between semantic content and spontaneous categorisation.

One of the central motivations of the present study was to move beyond the traditional major–minor dichotomy that has dominated research on musical mode to date. The results indicate that this distinction remains a robust organising principle, but its expression differs across the senses. Major modes were consistently associated with more positive and nature-related imagery, whereas minor modes were linked to darker and negatively valenced themes. In the free-sorting rationales, this separation was reflected affectively, with major modes more frequently described using Happy/Positive terms and minor modes more often associated with Sad/Melancholic or Tense descriptors.

Differentiation was also evident within modal categories, with Ionian more strongly associated with woody imagery and Mixolydian with grass and floral themes. Such distinctions indicate that even within the major category, modal identity is structured along multiple descriptive dimensions rather than reducible to a single shared affective profile. Importantly, the minor modes did not form a homogeneous category across the senses. Aeolian and Dorian were more closely associated with sadness-related themes, whereas Phrygian and Locrian showed stronger associations with threat-related and unsettling imagery.

Locrian displayed the most distinctive profile, occupying a more extreme position in the similarity spaces and was uniquely associated with Metal among the higher-ranking olfactory themes. Although metallic qualities have been described as ambimodal material properties spanning multiple sensory domains (Spence *et al.*, 2021), metallic sensations linked to the chemical senses are typically negatively valenced (Reith and Spence, 2020), consistent with Locrian's broader pattern of Unpleasant and threat-related associations. One possible contributor to this distinctiveness lies in its intervallic structure: Locrian uniquely contains a diminished fifth above the tonic and increased minor second motion. These auditory features are associated with heightened dissonance and tension in interval-level research (Pillay *et al.*, data not shown).

The prominence of affective language in the free-sorting rationales further highlights the role of emotional dimensions in participants' organisation of the modes. Major modes were more frequently described using Happy/Positive terms, whereas minor modes were more often associated with Sad/Melancholic or Tense descriptors. This pattern aligns with prior work suggesting that crossmodal correspondences are often based on shared emotional valence (Palmer *et al.*, 2013; Zhou and Yamanaka, 2018). Related findings from non-Western musical systems suggest that tonal and intervallic structure can give rise to consistent emotional responses within specific musical traditions (e.g., Mathur *et al.*, 2015).

Notably, the modalities differed in the nature of their dominant themes. Affective language was particularly prominent in explicit free-sorting rationales, suggesting an underlying hedonic mechanism. By contrast, olfactory imagery was more often grounded in concrete object- or material-based categories (e.g., Floral, Damp, Woody), and visual imagery combined affective and scene-based elements showing an additional possible semantic correspondence that could underly associations between both olfactory and visual sensory domains. Importantly, the mechanisms underlying crossmodal correspondences are not mutually exclusive and are likely to operate in combination rather than isolation (Spence, 2011).

The cosine distance matrices derived from visual and olfactory imagery were very highly correlated (Spearman $\rho = 0.948$), with the Mantel test confirming the robustness of this association. This strong correspondence indicates that modes similar in visual imagery were also similar in terms of the olfactory imagery that they elicited, thus suggesting that the musical modes may initially have triggered semantic associations which were associated with modality-specific content. This pattern is also consistent with accounts of crossmodal mental imagery, in which stimulation in one sensory modality can elicit imagery in another modality (Spence and Deroy, 2013). Moreover, the hierarchical structure revealed by the free-sorting task closely mirrored the imagery-based organisation, indicating that the dimensions structuring participants' imagery were likewise reflected in their perceptual grouping behaviour. The consistency between imagery content and sorting structure suggests that musical modes, as midlevel auditory constructs, are associated with crossmodal mappings that extend beyond isolated feature correspondences (Spence and Di Stefano, 2026).

These findings extend prior work on crossmodal correspondences by demonstrating that structured auditory constructs, such as musical modes, can evoke stable imagery patterns across sensory domains that go beyond simple one-to-one feature mappings. Rather than linking a single acoustic property to a single attribute in another modality, listeners appear to associate modal configurations with coherent visual and olfactory semantic themes, and these associations are reflected in how the modes are spontaneously grouped.

5. Limitations and Future Work

This study was explicitly exploratory in nature: by using open-ended imagery prompts and a free-sorting task, our aim was to characterise participant-driven associations rather than test prespecified correspondences. While this design yielded structured semantic maps of visual and olfactory imagery elicited by musical modes, it does not establish whether these imagery-based structures generalise to direct perceptual experience. In particular, the present findings derive from imagined olfactory associations rather than exposure to real fragrances. A critical next step for research in this area is therefore to examine whether fragrance stimuli selected to reflect the dominant olfactory themes identified here evoke comparable visual imagery and perceptual organisation when experienced directly. Such work would allow for a direct comparison between imagery-based mappings and perceptual crossmodal correspondences, clarifying whether the structures observed in the present study reflect stable multisensory associations or are specific to the context of imagery elicitation.

It should be noted that the present study did not assess individual differences in mental imagery ability (e.g., aphantasia or hyperphantasia), which may have influenced the vividness and accessibility of mental imagery in one or more senses. Importantly, olfactory imagery is generally more difficult to generate and less vivid than visual imagery, with a notable proportion of individuals reporting little or no ability to voluntarily imagine odours (Stevenson and Case, 2005). Variability in participants' ability to generate olfactory imagery may have influenced the consistency of the responses obtained. Individual differences in imagery abilities/vividness have been shown to extend across multiple sensory modalities, including olfaction (e.g., Dance *et al.*, 2021), and future research might therefore incorporate measures of imagery ability to better account for such variability.

Another limitation concerns the cultural and demographic characteristics of the sample. Participants were drawn exclusively from the United Kingdom and were responding to Western diatonic musical modes; however, more detailed information regarding place of birth, cultural background, or duration of residence was not collected given constraints of the online platform used. English proficiency was also not assessed using a standardised measure, and was instead based on Prolific prescreening and self-report, which may introduce some variability in language comprehension. Although much of the existing literature on musical mode and crossmodal correspondences has similarly relied on Western tonal systems and Western participants, recent research on non-Western musical systems, such as the Chinese pentatonic modes (Gong, Shang, Jue, Zhi, Yu), suggests that organising principles may differ across cultural contexts (KangHao and Wang, 2025). The present findings may therefore reflect culturally learned associations linked to Western tonal familiarity rather than universal perceptual tendencies. Replication using non-Western modal systems and culturally diverse samples will be necessary to assess the generalisability of the observed structures.

In addition, the sample was heavily skewed toward female participants. Although crossmodal correspondences are typically considered to be widely shared across individuals, the gender imbalance present in our sample prevents direct examination of any potential gender-related variation. Moreover, the menstrual cycle was not controlled for, despite evidence that hormonal fluctuations influence olfactory sensitivity as well as the perceived intensity of olfactory stimuli (Stanić *et al.*, 2021). That said, the impact of such variations on olfactory mental imagery remains unclear. Accounting for such physiological factors in future research would allow for a more precise characterisation of individual variability in olfactory imagery.

Finally, a free-sorting task captures implicit organisational tendencies but allows participants to use heterogeneous grouping criteria (affect, similarity of timbre, imagined scenes, etc.), which increases interindividual variability. Complementary confirmatory tasks (e.g., forced-choice matching, ratings on identified semantic dimensions) would help quantify effect sizes and causal direction.

6. Implications and Applications

Beyond its theoretical contribution to crossmodal correspondences research, the results of the present study demonstrate an approach for examining how structured auditory stimuli are associated with patterned visual and olfactory imagery that does not rely on predefined sensory taxonomies. The olfactory imagery findings are particularly relevant in light of the absence of a universally accepted perceptual taxonomy for odours. Unlike domains such as pitch or colour, where relatively well-defined perceptual dimensions can be identified, the categorisation of odours remains less standardised and is often debated within the literature (e.g., Keller and Vosshall, 2016; Yeshurun and Sobel, 2010). Previous work has shown how consistency of categorical responses does not necessarily validate the primacy of those categories themselves (e.g., O'Mahony, 1983). In this context, imagery-based approaches may offer an indirect means of exploring how individuals naturally organise and describe odours, independent of commercial fragrance labels or imposed classification schemes.

More broadly, the convergence between mental imagery-derived similarity and spontaneous categorisation indicates that musical modes can systematically shape multisensory representations across the senses. Much of the existing published literature has tended to focus on assessing crossmodal correspondences involving simple sensory stimuli (e.g., Belkin *et al.*, 1997; Crisinel and Spence, 2012), such as individual tones, timbres, or colours. However, it is important to recognise that such conditions may have limited ecological validity, as individual sounds (notes) are rarely encountered in isolation outside the laboratory (cf. Spence *et al.*, 2026). In this respect, the present findings suggest that crossmodal correspondences may operate more meaningfully at the level of these midlevel structures, rather than through one-to-one mappings between isolated sensory features. While practical applications in areas such as sensory design or media contexts remain to be tested empirically, the present findings nevertheless establish a foundation for examining how tonal systems structure crossmodal perception in applied contexts.

Taken together, the present findings invite reconsideration of early proposals such as Piesse's (1867) 'Gamut of Odours', where possible analogies between musical notes and fragrance notes were first suggested. Rather than implying a simple, feature-level mapping between music notes and specific odours, the current results indicate that scent–sound relationships may operate at the level of midlevel auditory structure (Spence, 2021). Rather than linking single notes to individual scents, modal structure appears to organise the olfactory associations evoked by music. Future research may examine whether comparable relationships between audition and olfaction emerge at higher levels of structural complexity.

References

Agbor Epse Muluh, E., McCormack, J. C., Mo, Y., Garratt, M. and Peng, M. (2024). Gustatory and olfactory shifts during pregnancy and the postpartum period: a systematic review and meta-analysis, *Physiol. Behav.* **273**, 114388. DOI:10.1016/j.physbeh.2023.114388.

Arshamian, A. and Larsson, M. (2014). Same same but different: the case of olfactory imagery, *Frontiers in Psychology* **5**, 34. DOI:10.3389/fpsyg.2014.00034.

Belkin, K., Martin, R., Kemp, S. E. and Gilbert, A. N. (1997). Auditory pitch as a perceptual analogue to odor quality, *Psychol. Sci.* **8**, 340–342. DOI:10.1111/j.1467-9280.1997.tb00450.x.

Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology, *Qualitative Research in Psychology* **3**, 77–101. DOI:10.1191/1478088706qp063oa.

Britt, C. J., Storey, E., Woods, R. L., Stocks, N., Nelson, M. R., Murray, A. M., Ryan, J., Rance, G. and McNeil, J. J. (2025). Age-related hearing loss: a cross-sectional study of healthy older Australians, *Gerontology* **71**, 88–99. DOI:10.1159/000541895.

Chang, J. (2025). On the relationship between key signatures and music-induced emotions, *J. Arts Human.* **13**, 1–13. DOI:10.18533/journal.v13i4.2503.

Collier, W. G. and Hubbard, T. L. (2004). Musical scales and brightness evaluations: effects of pitch, direction, and scale mode, *Musicae Sci.* **8**, 151–173. DOI:10.1177/102986490400800203.

Crisinel, A.-S. and Spence, C. (2012). A fruity note: crossmodal associations between odors and musical notes, *Chem. Sens.* **37**, 151–158. DOI:10.1093/chemse/bjr085.

Dance, C. J., Ward, J. and Simner, J. (2021). What is the link between mental imagery and sensory sensitivity? Insights from aphantasia, *Perception* **50**, 757–782. DOI:10.1177/03010066211042186.

De Paoli, S. (2024). Further explorations on the use of Large Language Models for thematic analysis. Open-ended prompts, better terminologies and thematic maps, *Qual. Sozialforsch.* **25**, 5. DOI:10.17169/fqs-25.3.4196.

Di Stefano, N. and Spence, C. (2024). Perceptual similarity: Insights from crossmodal correspondences, *Rev. Philos. Psychol.* **15**, 997–1026. DOI:10.1007/s13164-023-00692-y.

Djordjevic, J., Zatorre, R. J., Petrides, M., Boyle, J. A. and Jones-Gotman, M. (2005). Functional neuroimaging of odor imagery, *NeuroImage* **24**, 791–801. DOI:10.1016/j.neuroimage.2004.09.035.

Doty, R. L., Shaman, P., Applebaum, S. L., Giberson, R., Siksorski, L. and Rosenberg, L. (1984). Smell identification ability: Changes with age, *Science* **226**, 1441–1443. DOI:10.1126/science.6505700.

Evans, K. K. and Treisman, A. (2010). Natural cross-modal mappings between visual and auditory features, *J. Vis.* **10**, 1–12. DOI:10.1167/10.1.6.

Faul, F., Erdfelder, E., Lang, A.-G. and Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences, *Behav. Res. Methods* **39**, 175–191. DOI:10.3758/BF03193146.

Flohr, E. L. R., Arshamian, A., Wieser, M. J., Hummel, C., Larsson, M., Mühlberger, A. and Hummel, T. (2014). The fate of the inner nose: odor imagery in patients with olfactory loss, *Neuroscience* **268**, 118–127. DOI:10.1016/j.neuroscience.2014.03.018.

Gallace, A. and Spence, C. (2006). Multisensory synesthetic interactions in the speeded classification of visual size, *Percept. Psychophys.* **68**, 1191–1203. DOI:10.3758/BF03193720.

Gottfried, J. A. and Zald, D. H. (2005). On the scent of human olfactory orbitofrontal cortex: Meta-analysis and comparison to non-human primates, *Brain Res. Rev.* **50**, 287–304. DOI:10.1016/j.brainresrev.2005.08.004.

Harashima, S., Yokosawa, K. and Asano, M. (2025). Categorical tonality perception modulates crossmodal correspondences between musical chords and colors, *Conscious. Cogn.* **132**, 103886. DOI:10.1016/j.concog.2025.103886.

Hossu, G., Fantin, L., Charroud, C., Felblinger, J., Jacquot, M. and Ceyte, H. (2024). Neural mechanisms of odour imagery induced by non-figurative visual cues, *Neuropsychologia* **196**, 108836. DOI:10.1016/j.neuropsychologia.2024.108836.

KangHao, C. and Wang, I. T. (2025). Sound-color cross-modal correspondences in the Chinese pentatonic modes played on traditional instruments, *Sci. Rep.* **15**, 39676. DOI:10.1038/s41598-025-23220-7.

Keller, A. and Vosshall, L. B. (2016). Olfactory perception of chemically diverse molecules, *BMC Neurosci.* **17**, 55. DOI:10.1186/s12868-016-0287-2.

Khalid, M. T. and Witmer, A.-P. (2025). Prompt engineering for large language model-assisted inductive thematic analysis, *Soc. Sci. Comput. Rev.* **44**, 3. DOI:10.1177/08944393251388098.

Kruskal, J. B. and Wish, M. (1978). *Multidimensional scaling*. Sage, Thousand Oaks, CA.

Lacey, S. and Lawson, R. (Eds) (2013). *Multisensory imagery*. Springer Science and Business Media, Dordrecht. DOI:10.1007/978-1-4614-5879-1.

Leclerc, M. P., Kellermann, T., Freiherr, J., Clemens, B., Habel, U. and Regenbogen, C. (2019). Externalization errors of olfactory source monitoring in healthy controls — an fMRI study, *Chem. Sens.* **44**, 593–606. DOI:10.1093/chemse/bjz055.

Lim, J., Wood, A. and Green, B. G. (2009). Derivation and evaluation of a labeled hedonic scale, *Chem. Sens.* **34**, 739–751. DOI:10.1093/chemse/bjp054.

Maimon, N. B., Lamy, D. and Eitan, Z. (2020). Crossmodal correspondence between tonal hierarchy and visual brightness: associating syntactic structure and perceptual dimensions across modalities, *Multisens. Res.* **33**, 805–836. DOI:10.1163/22134808-bja10006.

Mantel, N. (1967). The detection of disease clustering and a generalized regression approach, *Cancer Res.* **27**, 209–220.

Marks, L. E. (1978). *The unity of the senses*. Academic Press, San Diego, CA. DOI:10.1016/C2013-0-11140-3.

Mathur, A., Vijayakumar, S. H., Chakrabarti, B. and Singh, N. C. (2015). Emotional responses to Hindustani rāga music: the role of musical structure, *Front. Psychol.* **6**, 513. DOI:10.3389/fpsyg.2015.00513.

Motoki, K., Marks, L. E. and Velasco, C. (2023). Reflections on cross-modal correspondences: current understanding and issues for future research, *Multisens. Res.* **37**, 1–23. DOI:10.1163/22134808-bja10114.

Ohtake, Y., Tanaka, K. and Yamamoto, K. (2023). How many categories are there in crossmodal correspondences? A study based on exploratory factor analysis, *PLoS ONE* **18**, e0294141. DOI:10.1371/journal.pone.0294141.

O'Mahony, M. (1983). Gustatory responses to nongustatory stimuli, *Perception* **12**, 627–633. DOI:10.1068/p120627.

Ozilgen, S. (2021). Tasting ancient Greek modes: does culinary arts education make a difference? *Int. J. Gastron. Food Sci.* **26**, 100419. DOI:10.1016/j.ijgfs.2021.100419.

Palmer, S. E., Langlois, T. A. and Schloss, K. B. (2016). Music-to-color associations of single-line piano melodies in non-synesthetes, *Multisens. Res.* **29**, 157–193. DOI:10.1163/22134808-00002486.

Palmer, S. E., Schloss, K. B., Xu, Z. and Prado-León, L. R. (2013). Music-color associations are mediated by emotion, *Proc. Natl. Acad. Sci. USA* **110**, 8836–8841. DOI:10.1073/pnas.1212562110.

Parise, C. V., Knorre, K. and Ernst, M. O. (2014). Natural auditory scene statistics shapes human spatial hearing, *Proc. Natl. Acad. Sci. USA* **111**, 6104–6108. DOI:10.1073/pnas.1322705111.

Piesse, G. W. S. (1867). *The art of perfumery and the methods of obtaining the odors of plants: With instructions for the manufacture of perfumes for the handkerchief, scented powders, odorous vinegars, dentifrices, pomatums, cosmetics, perfumed soap, etc., to which is added an appendix on preparing artificial fruit-essences, etc*. Lindsay and Blakiston, Philadelphia, PA.

Pimentel, O., Chuquichambi, E. G., Spence, C. and Velasco, C. (2025). The diatonic sound of scent imagery, *Perception* **54**, 689–714. DOI:10.1177/03010066251342011.

R Core Team (2025). *R: A language and environment for statistical computing (Version 4.5.1)*. R Foundation for Statistical Computing, Vienna. Available at https://www.R-project.org/.

Ramos, D., Bueno, J. L. O. and Bigand, E. (2011). Manipulating Greek musical modes and tempo affects perceived musical emotion in musicians and nonmusicians, *Braz. J. Med. Biol. Res.* **44**, 165–172. DOI:10.1590/S0100-879X2010007500148.

Reith, A. J. M. and Spence, C. (2020). The mystery of "metal mouth" in chemotherapy, *Chem. Sens.* **45**, 73–84. DOI:10.1093/chemse/bjz076.

Reymore, L. and Lindsey, D. T. (2025). Color and tone color: Audiovisual crossmodal correspondences with musical instrument timbre, *Front. Psychol.* **15**, 1520131. DOI:10.3389/fpsyg.2024.1520131.

Salton, G. and Buckley, C. (1988). Term-weighting approaches in automatic text retrieval, *Inform. Process. Manage.* **24**, 513–523. DOI:10.1016/0306-4573(88)90021-0.

Sauvé, S. A., Satkunarajah, P., Cooke, S., Demirkaplan, Ö., Follett, A. and Zendel, B. R. (2024). Age and familiarity effects on musical memory, *PLoS ONE* **19**, e0305969. DOI:10.1371/journal.pone.0305969.

Sepehr, M. M., Brown, J. V., Ettlinger, G. and Skreczek, W. (1988). The relationship between metaphoric and crossmodal abilities during development, *Int. J. Neurosci.* **38**, 53–67. DOI:10.3109/00207458809000482.

Spence, C. (2011). Crossmodal correspondences: a tutorial review, *Attent. Percept. Psychophys.* **73**, 971–995. DOI:10.3758/s13414-010-0073-7.

Spence, C. (2020). Assessing the role of emotional mediation in explaining crossmodal correspondences involving musical stimuli, *Multisens. Res.* **33**, 1–29. DOI:10.1163/22134808-20191469.

Spence, C. (2021). Musical scents: on the surprising absence of scented musical/auditory events entertainments, and experiences, *i-Perception* **12**, 1–31. DOI:10.1177/20416695211038747.

Spence, C. (2022). "Tasting imagination": What role chemosensory mental imagery in multisensory flavour perception? *Multisensory Research* **17**(1), 1–17. DOI:10.1163/22134808-bja10091.

Spence, C. (2023). Explaining visual shape-taste crossmodal correspondences, *Multisens. Res.* **36**, 313–345. DOI:10.1163/22134808-bja10096.

Spence, C. (2024). What is the relation between chemosensory perception and chemosensory mental imagery? *Multisens. Res.* **37**, 365–394. DOI:10.1163/22134808-bja10130.

Spence, C., Carvalho, F. and Howes, D. (2021). Metallic: a bivalent, ambimodal material property? *i-Perception* **12**, 1–33. DOI:10.1177/20416695211037710.

Spence, C. and Deroy, O. (2013). Crossmodal mental imagery, in: *Multisensory imagery: Theory and applications*, S. Lacey and R. Lawson (Eds), pp. 157–183. Springer, New York, NY. DOI:10.1007/978-1-4614-5879-1_9.

Spence, C. and Di Stefano, N. (2026). Mid-level audiovisual crossmodal correspondences: a narrative review, *Multisens. Res.* **39**, 99–137. DOI:10.1163/22134808-bja10175.

Spence, C., Di Stefano, N., Reinoso-Carvalho, F., Mesz, B. and Zacharakis, A. (2026). 'Play the fragrance': designing musical soundscapes to match fragrances based on olfactory-auditory crossmodal correspondences, *i-Perception* **17**, 1–33. DOI:10.1177/20416695251409265.

Stanić, Ž., Pribisalić, A., Bošković, M., Bućan Cvitanić, J., Boban, K., Bašković, G., Bartulić, A., Demo, S., Polašek, O. and Kolčić, I. (2021). Does each menstrual cycle elicit a distinct effect on olfactory and gustatory perception? *Nutrients* **13**, 2509. DOI:10.3390/nu13082509.

Starr, A. and Srinivasan, M. (2018). Spatial metaphor and the development of cross-domain mappings in early childhood, *Dev. Psychol.* **54**, 1822–1832. DOI:10.1037/dev0000573.

Stevens, S. S. (1957). On the psychophysical law, *Psychol. Rev.* **64**, 153–181. DOI:10.1037/h0046162.

Stevenson, R. J. and Case, T. I. (2005). Olfactory imagery: a review, *Psychon. Bull. Rev.* **12**, 244–264. DOI:10.3758/BF03196369.

Stevenson, R. J., Rich, A. and Russell, A. (2012). The nature and origin of cross-modal associations to odours, *Perception* **41**(5), 606–619. DOI:10.1068/p7223.

Straehley, I. C. and Loebach, J. L. (2014). The influence of mode and musical experience on the attribution of emotions to melodic sequences, *Psychomusicol.: Music Mind Brain* **24**, 21–34. DOI:10.1037/pmu0000032.

Taitz, A., Shalom, D., Trevisan, M. and Mesz, B. (2019). The taste of scales and chords, in: *Anais Do Simpósio Brasileiro de Computação Musical (SBCM 2019)*, pp. 197–198. DOI:10.5753/sbcm.2019.10445.

Vainio, L., Wikström, A. and Vainio, M. (2025). Pitch-based correspondences related to abstract concepts, *Acta Psychol.* **253**, 104754. DOI:10.1016/j.actpsy.2025.104754.

Velasco, C., Woods, A. T., Deroy, O. and Spence, C. (2015). Hedonic mediation of the crossmodal correspondence between taste and shape, *Food Qual. Pref.* **41**, 151–158. DOI:10.1016/j.foodqual.2014.11.010.

Velasco, C., Woods, A. T., Marks, L. E., Cheok, A. D. and Spence, C. (2016). The semantic basis of taste-shape associations, *PeerJ* **4**, 1644. DOI:10.7717/peerj.1644.

Von Hornbostel, E. M. (1950). The unity of the senses, in: *A source book of Gestalt psychology*, W. D. Ellis (Ed.), pp. 210–216. Routledge and Kegan Paul, London. (a translation of von Hornbostel, E. M. (1927). Die Einheit der Sinne. Psyche 7, 83–89).

Walker, P. and Walker, L. (2012). Size–brightness correspondence: Crosstalk and congruity among dimensions of connotative meaning, *Attent. Percept. Psychophys.* **74**, 1226–1240. DOI:10.3758/s13414-012-0297-9.

Wang, Q. J. and Spence, C. (2017). The role of pitch and tempo in sound-temperature crossmodal correspondences, *Multisens. Res.* **30**, 307–320. DOI:10.1163/22134808-00002564.

Wasano, K., Nakagawa, T. and Ogawa, K. (2022). Prevalence of hearing impairment by age: 2nd to 10th decades of life, *Biomedicines* **10**, 1431. DOI:10.3390/biomedicines10061431.

Wood, J. B. and Harkins, S. W. (1987). Effects of age, stimulus selection, and retrieval environment on odor identification, *J. Gerontol.* **42**, 584–588. DOI:10.1093/GERONJ/42.6.584.

Yeshurun, Y. and Sobel, N. (2010). An odor is not worth a thousand words: from multidimensional odors to unidimensional odor objects, *Annu. Rev. Psychol.* **61**, 219–241. DOI:10.1146/annurev.psych.60.110707.163639.

Zacharakis, A. (2024). Sonic bouquet: Decoding cross-modal correspondences between timbre and scent, *Music Sci.* **7**, 20592043241274256. DOI:10.1177/20592043241274258.

Zacharakis, A. (2025). The poetry of senses: Exploring semantic mediation in timbre-aroma correspondences, *Front. Psychol.* **16**, 1520046. DOI:10.3389/fpsyg.2025.1520046.

Zhou, C. and Yamanaka, T. (2018). How does congruence of scent and music affect people's emotions, *Int. J. Affect. Eng.* **17**, 127–136. DOI:10.5057/ijae.ijae-d-17-00032.

Table A1.
Full descriptive statistics for visual mental imagery themes by musical mode

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Aeolian	Sadness	51	10.81	40.80	125	7
Aeolian	Movement	26	5.51	10.32	252	7
Aeolian	Nature	26	5.51	10.04	259	7
Aeolian	Dark	25	5.30	14.62	171	7
Aeolian	Stress	20	4.24	19.80	101	5
Aeolian	Female figure	20	4.24	20.20	99	7
Aeolian	Rain	20	4.24	22.73	88	7
Aeolian	Wood	19	4.03	14.84	128	7
Aeolian	Floral	17	3.60	14.78	115	7
Aeolian	Daytime	16	3.39	10.06	159	7
Aeolian	Historical setting	16	3.39	15.69	102	7
Aeolian	Gathering	15	3.18	10.34	145	7
Aeolian	Urban	14	2.97	16.28	86	7
Aeolian	Oceanic	13	2.75	22.03	59	6
Aeolian	Solitude	13	2.75	18.06	72	7
Aeolian	Dance	12	2.54	15.38	78	7
Aeolian	Window	12	2.54	19.67	61	7
Aeolian	Funeral	11	2.33	29.73	37	5
Aeolian	Nighttime	11	2.33	20.00	55	6
Aeolian	Cold	11	2.33	31.43	35	7
Aeolian	Abandoned/Decay	10	2.12	20.00	50	6
Aeolian	Anticipation	9	1.91	19.57	46	7
Aeolian	Contemplation	7	1.48	21.88	32	7
Aeolian	Hospital	6	1.27	30.00	20	5
Aeolian	Religious	6	1.27	25.00	24	7
Aeolian	Romantic	6	1.27	12.00	50	7
Aeolian	Sense of danger	5	1.06	5.56	90	5
Aeolian	Family	5	1.06	5.56	90	6
Aeolian	Candle	5	1.06	21.74	23	7
Aeolian	Male figure	5	1.06	12.82	39	7
Aeolian	Kitchen	4	0.85	20.00	20	6
Aeolian	Book/Paper	4	0.85	10.00	40	7
Aeolian	Fire	4	0.85	9.52	42	7
Aeolian	Winter	4	0.85	16.67	24	7
Aeolian	Wedding	3	0.64	13.64	22	4
Aeolian	Summer	3	0.64	5.26	57	5
Aeolian	Childhood	3	0.64	3.03	99	7
Aeolian	Spring	2	0.42	6.06	33	6
Aeolian	Autumn	2	0.42	10.53	19	7
Aeolian	Coffee	2	0.42	8.00	25	7
Aeolian	Food	2	0.42	5.41	37	7
Aeolian	Happiness	2	0.42	2.00	100	7
Aeolian	School	2	0.42	6.67	30	7
Aeolian	War	1	0.21	12.50	8	5

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Aeolian	Baked goods	1	0.21	2.78	36	7
Aeolian	Calm/Comfort	1	0.21	1.30	77	7
Dorian	Movement	40	8.08	15.87	252	7
Dorian	Sadness	34	6.87	27.20	125	7
Dorian	Dark	33	6.67	19.30	171	7
Dorian	Nature	26	5.25	10.04	259	7
Dorian	Gathering	25	5.05	17.24	145	7
Dorian	Historical setting	25	5.05	24.51	102	7
Dorian	Wood	23	4.65	17.97	128	7
Dorian	Rain	22	4.44	25.00	88	7
Dorian	Female figure	19	3.84	19.19	99	7
Dorian	Stress	18	3.64	17.82	101	5
Dorian	Solitude	18	3.64	25.00	72	7
Dorian	Funeral	17	3.43	45.95	37	5
Dorian	Daytime	15	3.03	9.43	159	7
Dorian	Abandoned/Decay	12	2.42	24.00	50	6
Dorian	Oceanic	11	2.22	18.64	59	6
Dorian	Book/Paper	11	2.22	27.50	40	7
Dorian	Urban	11	2.22	12.79	86	7
Dorian	Window	10	2.02	16.39	61	7
Dorian	Nighttime	9	1.82	16.36	55	6
Dorian	Dance	9	1.82	11.54	78	7
Dorian	Male Figure	9	1.82	23.08	39	7
Dorian	Romantic	8	1.62	16.00	50	7
Dorian	Hospital	7	1.41	35.00	20	5
Dorian	Sense of danger	7	1.41	7.78	90	5
Dorian	Contemplation	7	1.41	21.88	32	7
Dorian	Anticipation	6	1.21	13.04	46	7
Dorian	Autumn	6	1.21	31.58	19	7
Dorian	Childhood	6	1.21	6.06	99	7
Dorian	Cold	6	1.21	17.14	35	7
Dorian	Religious	6	1.21	25.00	24	7
Dorian	Family	5	1.01	5.56	90	6
Dorian	Calm/Comfort	5	1.01	6.49	77	7
Dorian	Floral	5	1.01	4.35	115	7
Dorian	Coffee	4	0.81	16.00	25	7
Dorian	Winter	4	0.81	16.67	24	7
Dorian	Food	3	0.61	8.11	37	7
Dorian	War	2	0.40	25.00	8	5
Dorian	Spring	2	0.40	6.06	33	6
Dorian	Fire	2	0.40	4.76	42	7
Dorian	Happiness	2	0.40	2.00	100	7
Dorian	School	2	0.40	6.67	30	7
Dorian	Kitchen	1	0.20	5.00	20	6

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Dorian	Baked goods	1	0.20	2.78	36	7
Dorian	Candle	1	0.20	4.35	23	7
Ionian	Nature	53	10.95	20.46	259	7
Ionian	Daytime	37	7.64	23.27	159	7
Ionian	Happiness	33	6.82	33.00	100	7
Ionian	Movement	33	6.82	13.10	252	7
Ionian	Gathering	29	5.99	20.00	145	7
Ionian	Family	25	5.17	27.78	90	6
Ionian	Floral	24	4.96	20.87	115	7
Ionian	Childhood	21	4.34	21.21	99	7
Ionian	Calm/Comfort	20	4.13	25.97	77	7
Ionian	Wood	16	3.31	12.50	128	7
Ionian	Dance	15	3.10	19.23	78	7
Ionian	Female figure	13	2.69	13.13	99	7
Ionian	Summer	12	2.48	21.05	57	5
Ionian	Historical setting	12	2.48	11.76	102	7
Ionian	School	12	2.48	40.00	30	7
Ionian	Romantic	10	2.07	20.00	50	7
Ionian	Window	10	2.07	16.39	61	7
Ionian	Oceanic	9	1.86	15.25	59	6
Ionian	Wedding	8	1.65	36.36	22	4
Ionian	Spring	8	1.65	24.24	33	6
Ionian	Baked goods	8	1.65	22.22	36	7
Ionian	Kitchen	7	1.45	35.00	20	6
Ionian	Book/Paper	7	1.45	17.50	40	7
Ionian	Fire	7	1.45	16.67	42	7
Ionian	Anticipation	5	1.03	10.87	46	7
Ionian	Dark	5	1.03	2.92	171	7
Ionian	Male Figure	5	1.03	12.82	39	7
Ionian	Winter	5	1.03	20.83	24	7
Ionian	Nighttime	4	0.83	7.27	55	6
Ionian	Coffee	4	0.83	16.00	25	7
Ionian	Cold	4	0.83	11.43	35	7
Ionian	Rain	3	0.62	3.41	88	7
Ionian	Solitude	3	0.62	4.17	72	7
Ionian	Urban	3	0.62	3.49	86	7
Ionian	Candle	2	0.41	8.70	23	7
Ionian	Contemplation	2	0.41	6.25	32	7
Ionian	Food	2	0.41	5.41	37	7
Ionian	Religious	2	0.41	8.33	24	7
Ionian	Sadness	2	0.41	1.60	125	7
Ionian	Funeral	1	0.21	2.70	37	5
Ionian	Hospital	1	0.21	5.00	20	5
Ionian	War	1	0.21	12.50	8	5

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Ionian	Autumn	1	0.21	5.26	19	7
Locrian	Dark	56	12.70	32.75	171	7
Locrian	Sense of danger	45	10.20	50.00	90	5
Locrian	Stress	33	7.48	32.67	101	5
Locrian	Movement	32	7.26	12.70	252	7
Locrian	Wood	24	5.44	18.75	128	7
Locrian	Historical setting	21	4.76	20.59	102	7
Locrian	Nature	17	3.85	6.56	259	7
Locrian	Urban	17	3.85	19.77	86	7
Locrian	Nighttime	16	3.63	29.09	55	6
Locrian	Solitude	15	3.40	20.83	72	7
Locrian	Abandoned/Decay	13	2.95	26.00	50	6
Locrian	Fire	12	2.72	28.57	42	7
Locrian	Gathering	11	2.49	7.59	145	7
Locrian	Daytime	9	2.04	5.66	159	7
Locrian	Female figure	9	2.04	9.09	99	7
Locrian	Rain	9	2.04	10.23	88	7
Locrian	Dance	8	1.81	10.26	78	7
Locrian	Window	8	1.81	13.11	61	7
Locrian	Anticipation	7	1.59	15.22	46	7
Locrian	Sadness	7	1.59	5.60	125	7
Locrian	Childhood	6	1.36	6.06	99	7
Locrian	Male Figure	6	1.36	15.38	39	7
Locrian	Family	5	1.13	5.56	90	6
Locrian	Calm/Comfort	5	1.13	6.49	77	7
Locrian	Cold	5	1.13	14.29	35	7
Locrian	Contemplation	5	1.13	15.63	32	7
Locrian	Food	5	1.13	13.51	37	7
Locrian	Funeral	4	0.91	10.81	37	5
Locrian	Book/Paper	4	0.91	10.00	40	7
Locrian	Candle	3	0.68	13.04	23	7
Locrian	Winter	3	0.68	12.50	24	7
Locrian	Hospital	2	0.45	10.00	20	5
Locrian	Summer	2	0.45	3.51	57	5
Locrian	Spring	2	0.45	6.06	33	6
Locrian	Autumn	2	0.45	10.53	19	7
Locrian	Baked goods	2	0.45	5.56	36	7
Locrian	Floral	2	0.45	1.74	115	7
Locrian	Happiness	2	0.45	2.00	100	7
Locrian	Religious	2	0.45	8.33	24	7
Locrian	Romantic	2	0.45	4.00	50	7
Locrian	School	2	0.45	6.67	30	7
Locrian	Coffee	1	0.23	4.00	25	7
Lydian	Nature	53	10.52	20.46	259	7

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Lydian	Movement	40	7.94	15.87	252	7
Lydian	Daytime	38	7.54	23.90	159	7
Lydian	Gathering	34	6.75	23.45	145	7
Lydian	Happiness	30	5.95	30.00	100	7
Lydian	Childhood	28	5.56	28.28	99	7
Lydian	Family	26	5.16	28.89	90	6
Lydian	Floral	24	4.76	20.87	115	7
Lydian	Calm/Comfort	23	4.56	29.87	77	7
Lydian	Summer	18	3.57	31.58	57	5
Lydian	Baked goods	14	2.78	38.89	36	7
Lydian	Dance	14	2.78	17.95	78	7
Lydian	Romantic	13	2.58	26.00	50	7
Lydian	Oceanic	12	2.38	20.34	59	6
Lydian	Spring	12	2.38	36.36	33	6
Lydian	Urban	11	2.18	12.79	86	7
Lydian	Anticipation	9	1.79	19.57	46	7
Lydian	Female figure	9	1.79	9.09	99	7
Lydian	Wood	9	1.79	7.03	128	7
Lydian	Food	8	1.59	21.62	37	7
Lydian	School	8	1.59	26.67	30	7
Lydian	Window	8	1.59	13.11	61	7
Lydian	Wedding	7	1.39	31.82	22	4
Lydian	Historical setting	6	1.19	5.88	102	7
Lydian	Contemplation	5	0.99	15.63	32	7
Lydian	Religious	4	0.79	16.67	24	7
Lydian	Book/Paper	3	0.60	7.50	40	7
Lydian	Candle	3	0.60	13.04	23	7
Lydian	Coffee	3	0.60	12.00	25	7
Lydian	Cold	3	0.60	8.57	35	7
Lydian	Dark	3	0.60	1.75	171	7
Lydian	Fire	3	0.60	7.14	42	7
Lydian	Rain	3	0.60	3.41	88	7
Lydian	Sadness	3	0.59	2.40	125	7
Lydian	Solitude	3	0.60	4.17	72	7
Lydian	Winter	3	0.60	12.50	24	7
Lydian	Stress	2	0.40	1.98	101	5
Lydian	Abandoned/Decay	2	0.40	4.00	50	6
Lydian	Autumn	2	0.40	10.53	19	7
Lydian	Male Figure	2	0.40	5.13	39	7
Lydian	Sense of danger	1	0.20	1.11	90	5
Lydian	War	1	0.20	12.50	8	5
Lydian	Kitchen	1	0.20	5.00	20	6
Mixolydian	Nature	75	15.43	28.96	259	7
Mixolydian	Floral	38	7.82	33.04	115	7

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Mixolydian	Movement	37	7.61	14.68	252	7
Mixolydian	Daytime	32	6.58	20.13	159	7
Mixolydian	Childhood	31	6.38	31.31	99	7
Mixolydian	Happiness	30	6.17	30.00	100	7
Mixolydian	Family	24	4.94	26.67	90	6
Mixolydian	Summer	22	4.53	38.60	57	5
Mixolydian	Calm/Comfort	21	4.32	27.27	77	7
Mixolydian	Gathering	20	4.12	13.79	145	7
Mixolydian	Female figure	16	3.29	16.16	99	7
Mixolydian	Dance	14	2.88	17.95	78	7
Mixolydian	Wood	11	2.26	8.59	128	7
Mixolydian	Food	10	2.06	27.03	37	7
Mixolydian	Baked goods	9	1.85	25.00	36	7
Mixolydian	Oceanic	8	1.65	13.56	59	6
Mixolydian	Spring	7	1.44	21.21	33	6
Mixolydian	Coffee	7	1.44	28.00	25	7
Mixolydian	Romantic	7	1.44	14.00	50	7
Mixolydian	Rain	6	1.23	6.82	88	7
Mixolydian	Kitchen	5	1.03	25.00	20	6
Mixolydian	Book/Paper	5	1.03	12.50	40	7
Mixolydian	Candle	5	1.03	21.74	23	7
Mixolydian	Wedding	4	0.82	18.18	22	4
Mixolydian	Sadness	4	0.82	3.20	125	7
Mixolydian	Urban	4	0.82	4.65	86	7
Mixolydian	Window	4	0.82	6.56	61	7
Mixolydian	Anticipation	3	0.62	6.52	46	7
Mixolydian	Autumn	3	0.62	15.79	19	7
Mixolydian	Cold	3	0.62	8.57	35	7
Mixolydian	Dark	3	0.62	1.75	171	7
Mixolydian	Historical setting	3	0.62	2.94	102	7
Mixolydian	Contemplation	2	0.41	6.25	32	7
Mixolydian	Fire	2	0.41	4.76	42	7
Mixolydian	Male figure	2	0.41	5.13	39	7
Mixolydian	School	2	0.41	6.67	30	7
Mixolydian	Solitude	2	0.41	2.78	72	7
Mixolydian	Winter	2	0.41	8.33	24	7
Mixolydian	Abandoned/Decay	1	0.21	2.00	50	6
Mixolydian	Nighttime	1	0.21	1.82	55	6
Mixolydian	Religious	1	0.21	4.17	24	7
Phrygian	Dark	46	9.62	26.90	171	7
Phrygian	Movement	44	9.21	17.46	252	7
Phrygian	Sense of danger	32	6.69	35.56	90	5
Phrygian	Stress	28	5.86	27.72	101	5
Phrygian	Urban	26	5.44	30.23	86	7

Table A1.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Phrygian	Wood	26	5.44	20.31	128	7
Phrygian	Rain	25	5.23	28.41	88	7
Phrygian	Sadness	24	5.02	19.20	125	7
Phrygian	Historical setting	19	3.97	18.63	102	7
Phrygian	Solitude	18	3.77	25.00	72	7
Phrygian	Nighttime	14	2.93	25.45	55	6
Phrygian	Female figure	13	2.72	13.13	99	7
Phrygian	Abandoned/Decay	12	2.51	24.00	50	6
Phrygian	Daytime	12	2.51	7.55	159	7
Phrygian	Fire	12	2.51	28.57	42	7
Phrygian	Gathering	11	2.30	7.59	145	7
Phrygian	Male figure	10	2.09	25.64	39	7
Phrygian	Nature	9	1.88	3.47	259	7
Phrygian	Window	9	1.88	14.75	61	7
Phrygian	Anticipation	7	1.46	15.22	46	7
Phrygian	Food	7	1.46	18.92	37	7
Phrygian	Oceanic	6	1.26	10.17	59	6
Phrygian	Book/Paper	6	1.26	15.00	40	7
Phrygian	Dance	6	1.26	7.69	78	7
Phrygian	Floral	5	1.05	4.35	115	7
Phrygian	Funeral	4	0.84	10.81	37	5
Phrygian	Hospital	4	0.84	20.00	20	5
Phrygian	Candle	4	0.84	17.39	23	7
Phrygian	Childhood	4	0.84	4.04	99	7
Phrygian	Coffee	4	0.84	16.00	25	7
Phrygian	Contemplation	4	0.84	12.50	32	7
Phrygian	Romantic	4	0.84	8.00	50	7
Phrygian	War	3	0.63	37.50	8	5
Phrygian	Autumn	3	0.63	15.79	19	7
Phrygian	Cold	3	0.63	8.57	35	7
Phrygian	Religious	3	0.63	12.50	24	7
Phrygian	Winter	3	0.63	12.50	24	7
Phrygian	Kitchen	2	0.42	10.00	20	6
Phrygian	Calm/Comfort	2	0.42	2.60	77	7
Phrygian	School	2	0.42	6.67	30	7
Phrygian	Baked goods	1	0.21	2.78	36	7
Phrygian	Happiness	1	0.21	1.00	100	7

For each canonical visual descriptor. raw counts and percentages within each mode are reported. together with overall frequencies across all modes.

Table A2.
Full descriptive statistics for olfactory mental imagery themes by musical mode

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Aeolian	Damp	46	13.18	22.55	204	7
Aeolian	Floral	35	10.03	14.06	249	7
Aeolian	Dusty	24	6.88	19.83	121	7
Aeolian	Woody	17	4.87	11.26	151	7
Aeolian	Smoke	16	4.58	15.09	106	7
Aeolian	Oceanic	15	4.30	34.09	44	6
Aeolian	Chemical	15	4.30	24.19	62	7
Aeolian	Clean	14	4.01	25.93	54	7
Aeolian	Nature	14	4.01	19.44	72	7
Aeolian	Earthy	12	3.44	18.18	66	7
Aeolian	Fresh	11	3.15	9.82	112	7
Aeolian	Fabric	10	2.87	25.64	39	6
Aeolian	Sweet	10	2.87	10.75	93	7
Aeolian	Grass	9	2.58	8.65	104	7
Aeolian	Candle	8	2.29	22.86	35	7
Aeolian	Cooked food	8	2.29	10.39	77	7
Aeolian	Coffee	7	2.01	15.91	44	7
Aeolian	Musk	7	2.01	16.28	43	7
Aeolian	Nostalgic	7	2.01	19.44	36	7
Aeolian	Perfume	7	2.01	17.07	41	7
Aeolian	Cold	6	1.72	14.63	41	7
Aeolian	Warm	6	1.72	12.77	47	7
Aeolian	Leather	5	1.43	45.45	11	6
Aeolian	Alcohol	5	1.43	11.11	45	7
Aeolian	Unpleasant	4	1.15	9.09	44	6
Aeolian	Book/Paper	4	1.15	16.67	24	7
Aeolian	Incense	4	1.15	18.18	22	7
Aeolian	Body odor	3	0.86	16.67	18	5
Aeolian	Urban	3	0.86	11.11	27	7
Aeolian	Herbs/Tea	2	0.57	15.38	13	5
Aeolian	Baked goods	2	0.57	2.22	90	7
Aeolian	Citrus	2	0.57	6.67	30	7
Aeolian	Spice	2	0.57	12.50	16	7
Aeolian	Strong	2	0.57	11.11	18	7
Aeolian	Baby	1	0.29	5.88	17	4
Aeolian	Light	1	0.29	6.25	16	4
Aeolian	Dark	1	0.29	8.33	12	5
Aeolian	Paint/Ink	1	0.29	16.67	6	5
Aeolian	Tobacco	1	0.29	10.00	10	6
Aeolian	Chocolate	1	0.29	7.14	14	7
Aeolian	Fruit	1	0.29	3.70	27	7
Dorian	Damp	47	14.37	23.04	204	7
Dorian	Woody	26	7.95	17.22	151	7

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Dorian	Dusty	23	7.03	19.01	121	7
Dorian	Earthy	21	6.42	31.82	66	7
Dorian	Floral	20	6.12	8.03	249	7
Dorian	Smoke	17	5.20	16.04	106	7
Dorian	Chemical	11	3.36	17.74	62	7
Dorian	Cooked food	10	3.06	12.99	77	7
Dorian	Fresh	10	3.06	8.93	112	7
Dorian	Musk	10	3.06	23.26	43	7
Dorian	Nature	10	3.06	13.89	72	7
Dorian	Cold	9	2.75	21.95	41	7
Dorian	Unpleasant	8	2.45	18.18	44	6
Dorian	Perfume	8	2.45	19.51	41	7
Dorian	Book/Paper	7	2.14	29.17	24	7
Dorian	Grass	7	2.14	6.73	104	7
Dorian	Oceanic	6	1.83	13.64	44	6
Dorian	Alcohol	6	1.83	13.33	45	7
Dorian	Body odor	5	1.53	27.78	18	5
Dorian	Nostalgic	5	1.53	13.89	36	7
Dorian	Sweet	5	1.53	5.38	93	7
Dorian	Urban	5	1.53	18.52	27	7
Dorian	Baked goods	4	1.22	4.44	90	7
Dorian	Chocolate	4	1.22	28.57	14	7
Dorian	Citrus	4	1.22	13.33	30	7
Dorian	Coffee	4	1.22	9.09	44	7
Dorian	Incense	4	1.22	18.18	22	7
Dorian	Strong	4	1.22	22.22	18	7
Dorian	Warm	4	1.22	8.51	47	7
Dorian	Tobacco	3	0.92	30.00	10	6
Dorian	Clean	3	0.92	5.56	54	7
Dorian	Dark	2	0.61	16.67	12	5
Dorian	Herbs/Tea	2	0.61	15.38	13	5
Dorian	Metal	2	0.61	11.11	18	5
Dorian	Popcorn	2	0.61	25.00	8	5
Dorian	Leather	2	0.61	18.18	11	6
Dorian	Candle	2	0.61	5.71	35	7
Dorian	Fruit	2	0.61	7.41	27	7
Dorian	Spice	2	0.61	12.50	16	7
Dorian	Paint/Ink	1	0.31	16.67	6	5
Ionian	Floral	55	15.80	22.09	249	7
Ionian	Woody	26	7.47	17.22	151	7
Ionian	Baked goods	23	6.61	25.56	90	7
Ionian	Fresh	22	6.32	19.64	112	7
Ionian	Grass	20	5.75	19.23	104	7

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Ionian	Sweet	18	5.17	19.35	93	7
Ionian	Cooked food	17	4.89	22.08	77	7
Ionian	Nature	16	4.60	22.22	72	7
Ionian	Clean	12	3.45	22.22	54	7
Ionian	Dusty	11	3.16	9.09	121	7
Ionian	Damp	10	2.87	4.90	204	7
Ionian	Nostalgic	9	2.59	25.00	36	7
Ionian	Smoke	9	2.59	8.49	106	7
Ionian	Fabric	8	2.30	20.51	39	6
Ionian	Warm	7	2.01	14.89	47	7
Ionian	Baby	6	1.72	35.29	17	4
Ionian	Light	6	1.72	37.50	16	4
Ionian	Coffee	6	1.72	13.64	44	7
Ionian	Fruit	6	1.72	22.22	27	7
Ionian	Musk	6	1.72	13.95	43	7
Ionian	Perfume	6	1.72	14.63	41	7
Ionian	Alcohol	5	1.44	11.11	45	7
Ionian	Chemical	5	1.44	8.06	62	7
Ionian	Oceanic	4	1.15	9.09	44	6
Ionian	Book/Paper	4	1.15	16.67	24	7
Ionian	Citrus	3	0.86	10.00	30	7
Ionian	Cold	3	0.86	7.32	41	7
Ionian	Body odor	2	0.57	11.11	18	5
Ionian	Herbs/Tea	2	0.57	15.38	13	5
Ionian	Popcorn	2	0.57	25.00	8	5
Ionian	Candle	2	0.57	5.71	35	7
Ionian	Chocolate	2	0.57	14.29	14	7
Ionian	Earthy	2	0.57	3.03	66	7
Ionian	Incense	2	0.57	9.09	22	7
Ionian	Spice	2	0.57	12.50	16	7
Ionian	Strong	2	0.57	11.11	18	7
Ionian	Urban	2	0.57	7.41	27	7
Ionian	Dark	1	0.29	8.33	12	5
Ionian	Metal	1	0.29	5.56	18	5
Ionian	Leather	1	0.29	9.09	11	6
Ionian	Tobacco	1	0.29	10.00	10	6
Ionian	Unpleasant	1	0.29	2.27	44	6
Locrian	Damp	36	11.36	17.65	204	7
Locrian	Dusty	32	10.09	26.45	121	7
Locrian	Woody	31	9.78	20.53	151	7
Locrian	Smoke	23	7.26	21.70	106	7
Locrian	Unpleasant	16	5.05	36.36	44	6
Locrian	Alcohol	12	3.79	26.67	45	7

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Locrian	Floral	12	3.79	4.82	249	7
Locrian	Fresh	12	3.79	10.71	112	7
Locrian	Cooked food	11	3.47	14.29	77	7
Locrian	Earthy	11	3.47	16.67	66	7
Locrian	Metal	10	3.15	55.56	18	5
Locrian	Chemical	9	2.84	14.52	62	7
Locrian	Cold	9	2.84	21.95	41	7
Locrian	Sweet	8	2.52	8.60	93	7
Locrian	Urban	7	2.21	25.93	27	7
Locrian	Candle	6	1.89	17.14	35	7
Locrian	Body odor	5	1.58	27.78	18	5
Locrian	Dark	5	1.58	41.67	12	5
Locrian	Book/Paper	5	1.58	20.83	24	7
Locrian	Coffee	5	1.58	11.36	44	7
Locrian	Fruit	5	1.58	18.52	27	7
Locrian	Grass	5	1.58	4.81	104	7
Locrian	Nature	5	1.58	6.94	72	7
Locrian	Musk	4	1.26	9.30	43	7
Locrian	Spice	4	1.26	25.00	16	7
Locrian	Strong	4	1.26	22.22	18	7
Locrian	Fabric	3	0.95	7.69	39	6
Locrian	Baked goods	3	0.95	3.33	90	7
Locrian	Clean	3	0.95	5.56	54	7
Locrian	Incense	3	0.95	13.64	22	7
Locrian	Perfume	3	0.95	7.32	41	7
Locrian	Paint/Ink	2	0.63	33.33	6	5
Locrian	Tobacco	2	0.63	20.00	10	6
Locrian	Chocolate	2	0.63	14.29	14	7
Locrian	Citrus	2	0.63	6.67	30	7
Locrian	Nostalgic	1	0.32	2.78	36	7
Locrian	Warm	1	0.32	2.13	47	7
Lydian	Floral	60	17.65	24.10	249	7
Lydian	Baked goods	29	8.53	32.22	90	7
Lydian	Fresh	27	7.94	24.11	112	7
Lydian	Sweet	25	7.35	26.88	93	7
Lydian	Grass	22	6.47	21.15	104	7
Lydian	Cooked food	15	4.41	19.48	77	7
Lydian	Woody	13	3.82	8.61	151	7
Lydian	Warm	11	3.24	23.40	47	7
Lydian	Fabric	10	2.94	25.64	39	6
Lydian	Damp	8	2.35	3.92	204	7
Lydian	Nature	8	2.35	11.11	72	7
Lydian	Oceanic	7	2.06	15.91	44	6

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Lydian	Alcohol	7	2.06	15.56	45	7
Lydian	Citrus	7	2.06	23.33	30	7
Lydian	Clean	7	2.06	12.96	54	7
Lydian	Coffee	7	2.06	15.91	44	7
Lydian	Nostalgic	7	2.06	19.44	36	7
Lydian	Dusty	6	1.76	4.96	121	7
Lydian	Urban	6	1.76	22.22	27	7
Lydian	Light	5	1.47	31.25	16	4
Lydian	Herbs/Tea	5	1.47	38.46	13	5
Lydian	Incense	5	1.47	22.73	22	7
Lydian	Cold	4	1.18	9.76	41	7
Lydian	Fruit	4	1.18	14.81	27	7
Lydian	Perfume	4	1.18	9.76	41	7
Lydian	Smoke	4	1.18	3.77	106	7
Lydian	Spice	4	1.18	25.00	16	7
Lydian	Baby	3	0.88	17.65	17	4
Lydian	Candle	3	0.88	8.57	35	7
Lydian	Musk	3	0.88	6.98	43	7
Lydian	Unpleasant	2	0.59	4.55	44	6
Lydian	Chocolate	2	0.59	14.29	14	7
Lydian	Earthy	2	0.59	3.03	66	7
Lydian	Metal	1	0.29	5.56	18	5
Lydian	Paint/Ink	1	0.29	16.67	6	5
Lydian	Popcorn	1	0.29	12.50	8	5
Lydian	Leather	1	0.29	9.09	11	6
Lydian	Tobacco	1	0.29	10.00	10	6
Lydian	Book/Paper	1	0.29	4.17	24	7
Lydian	Chemical	1	0.29	1.61	62	7
Lydian	Strong	1	0.29	5.56	18	7
Mixolydian	Floral	62	18.84	24.90	249	7
Mixolydian	Grass	30	9.12	28.85	104	7
Mixolydian	Baked goods	27	8.21	30.00	90	7
Mixolydian	Fresh	23	6.99	20.54	112	7
Mixolydian	Sweet	23	6.99	24.73	93	7
Mixolydian	Warm	16	4.86	34.04	47	7
Mixolydian	Nature	13	3.95	18.06	72	7
Mixolydian	Perfume	11	3.34	26.83	41	7
Mixolydian	Clean	10	3.04	18.52	54	7
Mixolydian	Woody	9	2.74	5.96	151	7
Mixolydian	Citrus	8	2.43	26.67	30	7
Mixolydian	Coffee	8	2.43	18.18	44	7
Mixolydian	Cooked food	8	2.43	10.39	77	7
Mixolydian	Damp	8	2.43	3.92	204	7

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Mixolydian	Baby	7	2.13	41.18	17	4
Mixolydian	Smoke	7	2.13	6.60	106	7
Mixolydian	Fabric	6	1.82	15.38	39	6
Mixolydian	Fruit	6	1.82	22.22	27	7
Mixolydian	Nostalgic	6	1.82	16.67	36	7
Mixolydian	Candle	5	1.52	14.29	35	7
Mixolydian	Light	4	1.22	25.00	16	4
Mixolydian	Oceanic	4	1.22	9.09	44	6
Mixolydian	Chemical	3	0.91	4.84	62	7
Mixolydian	Cold	3	0.91	7.32	41	7
Mixolydian	Earthy	3	0.91	4.55	66	7
Mixolydian	Musk	3	0.91	6.98	43	7
Mixolydian	Herbs/Tea	2	0.61	15.38	13	5
Mixolydian	Alcohol	2	0.61	4.44	45	7
Mixolydian	Chocolate	2	0.61	14.29	14	7
Mixolydian	Dusty	2	0.61	1.65	121	7
Mixolydian	Incense	2	0.61	9.09	22	7
Mixolydian	Popcorn	1	0.30	12.50	8	5
Mixolydian	Leather	1	0.30	9.09	11	6
Mixolydian	Book/Paper	1	0.30	4.17	24	7
Mixolydian	Spice	1	0.30	6.25	16	7
Mixolydian	Strong	1	0.30	5.56	18	7
Mixolydian	Urban	1	0.30	3.70	27	7
Phrygian	Damp	49	15.46	24.02	204	7
Phrygian	Smoke	30	9.46	28.30	106	7
Phrygian	Woody	29	9.15	19.21	151	7
Phrygian	Dusty	23	7.26	19.01	121	7
Phrygian	Chemical	18	5.68	29.03	62	7
Phrygian	Earthy	15	4.73	22.73	66	7
Phrygian	Unpleasant	13	4.10	29.55	44	6
Phrygian	Grass	11	3.47	10.58	104	7
Phrygian	Musk	10	3.15	23.26	43	7
Phrygian	Candle	9	2.84	25.71	35	7
Phrygian	Oceanic	8	2.52	18.18	44	6
Phrygian	Alcohol	8	2.52	17.78	45	7
Phrygian	Cooked food	8	2.52	10.39	77	7
Phrygian	Coffee	7	2.21	15.91	44	7
Phrygian	Cold	7	2.21	17.07	41	7
Phrygian	Fresh	7	2.21	6.25	112	7
Phrygian	Nature	6	1.89	8.33	72	7
Phrygian	Clean	5	1.58	9.26	54	7
Phrygian	Floral	5	1.58	2.01	249	7

Table A2.
(Continued)

Mode	Canonical label	*n*	% within mode visual	% within visual	Total *n*	*n* modes present
Phrygian	Metal	4	1.26	22.22	18	5
Phrygian	Citrus	4	1.26	13.33	30	7
Phrygian	Strong	4	1.26	22.22	18	7
Phrygian	Sweet	4	1.26	4.30	93	7
Phrygian	Body odor	3	0.95	16.67	18	5
Phrygian	Dark	3	0.95	25.00	12	5
Phrygian	Fruit	3	0.95	11.11	27	7
Phrygian	Urban	3	0.95	11.11	27	7
Phrygian	Popcorn	2	0.63	25.00	8	5
Phrygian	Fabric	2	0.63	5.13	39	6
Phrygian	Tobacco	2	0.63	20.00	10	6
Phrygian	Baked goods	2	0.63	2.22	90	7
Phrygian	Book/Paper	2	0.63	8.33	24	7
Phrygian	Incense	2	0.63	9.09	22	7
Phrygian	Perfume	2	0.63	4.88	41	7
Phrygian	Warm	2	0.63	4.26	47	7
Phrygian	Paint/Ink	1	0.32	16.67	6	5
Phrygian	Leather	1	0.32	9.09	11	6
Phrygian	Chocolate	1	0.32	7.14	14	7
Phrygian	Nostalgic	1	0.32	2.78	36	7
Phrygian	Spice	1	0.32	6.25	16	7

For each canonical smell descriptor. raw counts and percentages within each mode are reported. together with overall frequencies across all modes.

Table A3.
Pairwise cosine distance matrices computed from TF–IDF-weighted visual imagery themes

Mode	Ionian	Dorian	Phrygian	Lydian	Mixolydian	Aeolian	Locrian
Ionian	0.000	0.387	0.580	0.025	0.051	0.413	0.598
Dorian	0.387	0.000	0.131	0.406	0.454	0.062	0.240
Phrygian	0.580	0.131	0.000	0.583	0.640	0.186	0.059
Lydian	0.025	0.406	0.583	0.000	0.047	0.431	0.607
Mixolydian	0.051	0.454	0.640	0.047	0.000	0.450	0.653
Aeolian	0.413	0.062	0.186	0.431	0.450	0.000	0.317
Locrian	0.598	0.240	0.059	0.607	0.653	0.317	0.000

Smaller values indicate greater similarity between modes.

Table A4.
Pairwise cosine distance matrices computed from TF–IDF-weighted smell imagery themes

Mode	Ionian	Lydian	Mixolydian	Aeolian	Dorian	Phrygian	Locrian
Ionian	0.000	0.042	0.057	0.251	0.360	0.504	0.414
Lydian	0.042	0.000	0.030	0.327	0.465	0.625	0.527
Mixolydian	0.057	0.030	0.000	0.343	0.493	0.647	0.588
Aeolian	0.251	0.327	0.343	0.000	0.078	0.149	0.180
Dorian	0.360	0.465	0.493	0.078	0.000	0.063	0.082
Phrygian	0.504	0.625	0.647	0.149	0.063	0.000	0.068
Locrian	0.414	0.527	0.588	0.180	0.082	0.068	0.000

Smaller values indicate greater similarity between modes.

Table A5.
Free-sorting co-occurrence counts between musical modes

Mode 1	Mode 2	*n* together
Locrian	Phrygian	167
Lydian	Mixolydian	166
Ionian	Lydian	151
Ionian	Mixolydian	133
Dorian	Phrygian	132
Aeolian	Dorian	125
Aeolian	Locrian	118
Dorian	Locrian	112
Aeolian	Phrygian	108
Aeolian	Mixolydian	55
Aeolian	Lydian	51
Aeolian	Ionian	47
Dorian	Ionian	45
Dorian	Lydian	36
Ionian	Locrian	32
Mixolydian	Phrygian	32
Dorian	Mixolydian	30
Locrian	Lydian	28
Lydian	Phrygian	28
Locrian	Mixolydian	26
Ionian	Phrygian	23

Values report the number of participant-groups in which each unordered pair of musical modes was placed in the same group during the free-sorting task. Counts were aggregated across 677 participant-groups

Table A6.
Free-sorting rationale theme counts and percentages by musical mode

Mode	Theme	n	% within mode
Aeolian	Sad/Melancholic	92	38.33
Aeolian	Happy/Positive	30	12.50
Aeolian	Tense/Anxious	21	8.75
Aeolian	Calm/Peaceful	15	6.25
Aeolian	Creepy/Unsettling	14	5.83
Aeolian	Dark	14	5.83
Aeolian	Nostalgic/Reflective	12	5.00
Aeolian	Similar Timbre/Texture	12	5.00
Aeolian	Emotional Valence mixed/Neutral	10	4.17
Aeolian	Bright	6	2.50
Aeolian	High pitch	5	2.08
Aeolian	Food/Sensory	2	0.83
Aeolian	Warmth/Comfort	2	0.83
Aeolian	Energetic/Active	1	0.42
Aeolian	Fast	1	0.42
Aeolian	Low pitch	1	0.42
Aeolian	Odd one out	1	0.42
Aeolian	Slow	1	0.42
Dorian	Sad/Melancholic	99	41.25
Dorian	Tense/Anxious	26	10.83
Dorian	Dark	23	9.58
Dorian	Creepy/Unsettling	16	6.67
Dorian	Happy/Positive	16	6.67
Dorian	Calm/Peaceful	11	4.58
Dorian	Nostalgic/Reflective	11	4.58
Dorian	Similar Timbre/Texture	8	3.33
Dorian	Emotional valence mixed/Neutral	6	2.50
Dorian	Low pitch	6	2.50
Dorian	Threat/Danger	4	1.67
Dorian	Odd one out	3	1.25
Dorian	Slow	3	1.25
Dorian	Fast	2	0.83
Dorian	Food/Sensory	2	0.83
Dorian	Warmth/Comfort	2	0.83
Dorian	Bright	1	0.42
Dorian	Energetic/Active	1	0.42
Ionian	Happy/Positive	106	44.54
Ionian	Calm/Peaceful	24	10.08
Ionian	Bright	17	7.14
Ionian	Nostalgic/Reflective	13	5.46
Ionian	Sad/Melancholic	13	5.46
Ionian	Similar timbre/Texture	11	4.62
Ionian	Emotional valence mixed/Neutral	10	4.20
Ionian	Warmth/Comfort	10	4.20

Table A6.
(Continued)

Mode	Theme	n	% within mode
Ionian	Tense/Anxious	7	2.94
Ionian	Dark	6	2.52
Ionian	High pitch	4	1.68
Ionian	Low pitch	4	1.68
Ionian	Creepy/Unsettling	3	1.26
Ionian	Energetic/Active	3	1.26
Ionian	Fast	2	0.84
Ionian	Food/Sensory	2	0.84
Ionian	Slow	2	0.84
Ionian	Odd one out	1	0.42
Locrian	Sad/Melancholic	70	29.05
Locrian	Creepy/Unsettling	44	18.26
Locrian	Tense/Anxious	41	17.01
Locrian	Dark	25	10.37
Locrian	Happy/Positive	14	5.81
Locrian	Nostalgic/Reflective	9	3.73
Locrian	Similar Timbre/Texture	8	3.32
Locrian	High Pitch	6	2.49
Locrian	Calm/Peaceful	5	2.07
Locrian	Emotional valence mixed/Neutral	5	2.07
Locrian	Odd one out	5	2.07
Locrian	Threat/Danger	2	0.83
Locrian	Warmth/Comfort	2	0.83
Locrian	Bright	1	0.41
Locrian	Energetic/Active	1	0.41
Locrian	Fast	1	0.41
Locrian	Food/Sensory	1	0.41
Locrian	Slow	1	0.41
Lydian	Happy/Positive	114	47.70
Lydian	Calm/Peaceful	31	12.97
Lydian	Bright	17	7.11
Lydian	Sad/Melancholic	16	6.69
Lydian	Nostalgic/Reflective	12	5.02
Lydian	Similar timbre/Texture	12	5.02
Lydian	Emotional valence mixed/Neutral	7	2.93
Lydian	Tense/Anxious	7	2.93
Lydian	Low pitch	6	2.51
Lydian	Warmth/Comfort	5	2.09
Lydian	High pitch	3	1.26
Lydian	Dark	2	0.84
Lydian	Energetic/Active	2	0.84
Lydian	Food/Sensory	2	0.84
Lydian	Slow	2	0.84
Lydian	Creepy/Unsettling	1	0.42

Table A6.
(Continued)

Mode	Theme	n	% within mode
Mixolydian	Happy/Positive	110	45.83
Mixolydian	Calm/Peaceful	33	13.75
Mixolydian	Sad/Melancholic	22	9.17
Mixolydian	Nostalgic/Reflective	17	7.08
Mixolydian	Bright	14	5.83
Mixolydian	Similar timbre/Texture	11	4.58
Mixolydian	Emotional valence mixed/Neutral	7	2.92
Mixolydian	High pitch	6	2.50
Mixolydian	Warmth/Comfort	5	2.08
Mixolydian	Energetic/Active	3	1.25
Mixolydian	Slow	3	1.25
Mixolydian	Tense/Anxious	3	1.25
Mixolydian	Creepy/Unsettling	2	0.83
Mixolydian	Food/Sensory	2	0.83
Mixolydian	Dark	1	0.42
Mixolydian	Low pitch	1	0.42
Phrygian	Sad/Melancholic	82	33.61
Phrygian	Creepy/Unsettling	39	15.98
Phrygian	Tense/Anxious	39	15.98
Phrygian	Dark	23	9.43
Phrygian	Nostalgic/Reflective	12	4.92
Phrygian	Similar timbre/Texture	10	4.10
Phrygian	Happy/Positive	8	3.28
Phrygian	Emotional valence mixed/Neutral	6	2.46
Phrygian	Calm/Peaceful	5	2.05
Phrygian	Low pitch	4	1.64
Phrygian	Odd one out	3	1.23
Phrygian	Threat/Danger	3	1.23
Phrygian	Food/Sensory	2	0.82
Phrygian	High pitch	2	0.82
Phrygian	Slow	2	0.82
Phrygian	Bright	1	0.41
Phrygian	Energetic/Active	1	0.41
Phrygian	Fast	1	0.41
Phrygian	Warmth/Comfort	1	0.41

Entries report the number of free-sorting rationale responses (n) and the percentage of rationale responses within each musical mode assigned to each theme. Percentages are computed within mode.