DATA ANALYSIS ON "MUSIC AND MEMORY" RESEARCH IN MUSIC AND HEALTH SCIENCE CONTEXTS

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Abstract

This study presents a data-driven examination of research published between 2020 and 2025 on music and memory across music scholarship and health sciences, with a particular focus on dementia and Alzheimer's disease. Analysis of the first dataset shows that while health-science publications increasingly acknowledge music's cognitive and therapeutic relevance, they rarely integrate structural musical analysis; conversely, music-domain studies maintain analytical depth yet remain detached from clinical contexts. The second dataset surveys state-of-the-art technologies in chord recognition and music tokenization, demonstrating that Roman numeral analysis—often treated as the most meaningful tokenization of tonal harmony—still depends on expert-annotated datasets and lacks fully automatic, scalable systems. Overall, the findings highlight a persistent interdisciplinary gap and the need for real-time tools linking musical structure with behavioral, cognitive, and neural data.

Dataset available at:

https://docs.google.com/spreadsheets/d/14usnO_80mCKaGabrupDsS8046au0ueA3/edit?usp=sharing&ouid=105191505185184701711&rtpof=true&sd=true

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1 Introduction

Music has long been recognized as more than an organized sequence of sounds; it functions as a medium through which affect, memory, and social meaning are shaped and communicated. At the same time, its internal organization—its patterns of harmony, melody, and form—and their impact on cognition and behaviour remain only partially understood. In particular, the relationship between music and the human mind—how musical structure engages perception, memory, and emotion—remains insufficiently theorized and methodologically underdeveloped across contemporary interdisciplinary research. Understanding how musical structure interacts with the human mind is particularly urgent in contexts such as *dementia* and *Alzheimer's disease*, where memory, identity, and cognitive continuity are profoundly challenged and where music often emerges as one of the few stimuli capable of eliciting preserved responses.

Against this backdrop, this study presents a data-driven analysis of the evolving relationship between *music, memory, and health sciences*, with particular attention to *dementia* and *Alzheimer's disease* as critical case domains in which music–mind interactions become especially salient. Drawing on a dataset of research published between *2020 and 2025*, available at the link provided under the main title of this article, the analysis identifies key patterns, recurring gaps, and methodological challenges across two major domains: the *therapeutic use of music in health sciences* and the *structural analysis of music in academic scholarship*. It examines how each domain constructs its background, formulates problem statements, defines goals, and selects methods. A consistent dissociation emerges: health sciences increasingly recognize music's cognitive and affective relevance but rarely incorporate formal music-theoretical or structural analysis, whereas music scholarship maintains analytical depth but remains largely disconnected from *real-time clinical contexts*.

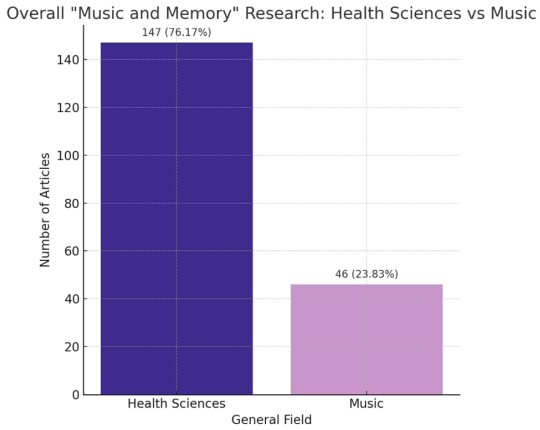
To address this disciplinary and methodological disconnect, the study examines a *real-time software system* developed as part of my graduate research. The system converts symbolic musical input into discrete, tokenized units to enable automated *Roman numeral analysis* and temporally aligns these tokens with *EEG signals* and *facial expression*

measurements. This design yields a *multimodal dataset* that links musical structure to cognitive and physiological responses in real time. By engaging with both established and recent approaches to *music tokenization*, *chord recognition*, and *Roman numeral analysis*, the project aims to contribute an interpretable and computationally tractable framework at the intersection of music theory, artificial intelligence, and neuroscience.

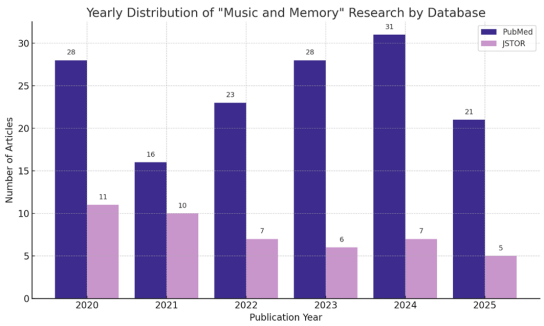
2 Data Analysis Part 1: "Music and Memory" Research in Music and Health Sciences

As the first stage of the broader analysis, this section maps how contemporary *music and memory* research is distributed between *Health Sciences* and *Music*, with particular emphasis on *dementia* and *Alzheimer's* care as critical test domains for *music–mind* interactions. The analysis examines how existing studies define their *background*, specify *problem areas*, formulate *goals*, select *methods*, and articulate *conclusions*, in order to identify where *structural music theory* and associated *analytical tools* are absent or underutilized.

Figure 1a shows that *"music and memory"* research is heavily concentrated in the *health sciences* (76.17%), with a comparatively smaller proportion of studies situated in the *music* domain (23.83%). *Figure 1b* further illustrates a stable annual publication trend across *PubMed* and *JSTOR* between *2020 and 2025*. Over this period, PubMed consistently leads in article volume, underscoring its central role in health-oriented work on music and memory, whereas JSTOR contributes fewer but steady publications, reflecting a more selective and discipline-specific engagement from music scholarship. A notable increase appears in *2024*, with *31 publications* in PubMed and *7* in JSTOR, suggesting a heightened interdisciplinary interest in music and memory across both health sciences and the humanities.



(a) Music and memory research distribution in Music and Health Sciences.



(b) Music and memory research (2020–2025) by database (PubMed and JSTOR).

Figure 1: Distribution of music and memory research.

Figure 2 details how *"music and memory"* research divides into *specific fields* across *Health Sciences* and *Music*. On the health side, the distribution is dominated by *behavioral sciences*, followed by *neuroscience*, *cognitive psychology*, and *geriatrics*, reflecting a primarily *biomedical* and clinical framing of *dementia* and *Alzheimer's* care. On the music side, publications cluster around *music cognition and theory*, *musicology*, and *music therapy*, indicating a focus on musical structure, perception, and practice as they relate to memory and wellbeing.

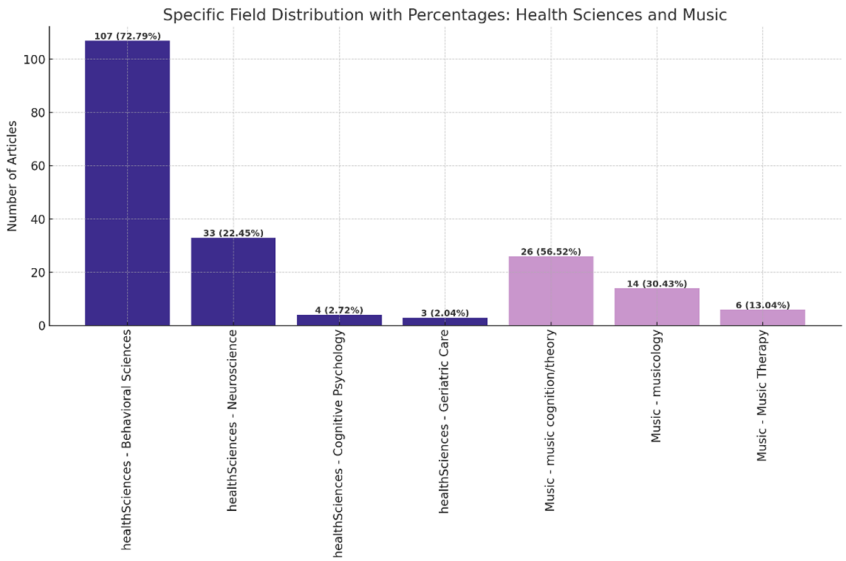
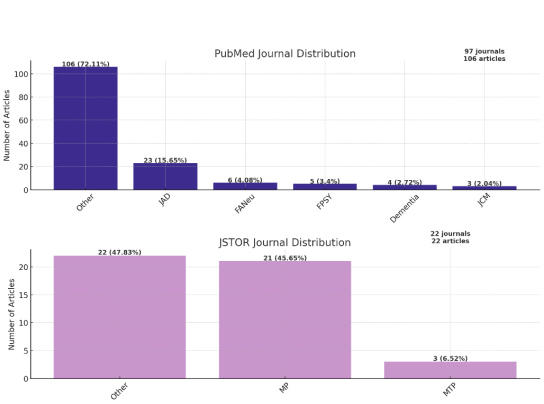


Figure 2: Specific field distributions in Music and Health Sciences.

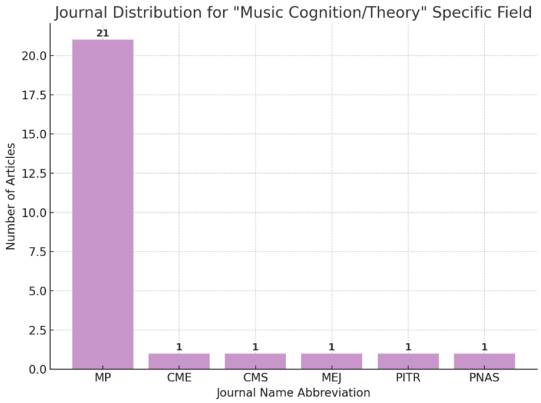
Figure 3a reveals a marked difference in *"music and memory"* publication patterns be-

tween *PubMed* and *JSTOR*. Within PubMed, research is distributed across more than 100 specialized medical journals, with the *Journal of Alzheimer's Disease (JAD)* alone contributing 23 articles and the remaining 99 journals publishing the rest. In JSTOR, by contrast, output is highly concentrated: *Music Perception* accounts for 21 articles (45.65%), *Music Therapy Perspectives* adds 3, and 21 other journals contribute a single article each. This concentration raises a key question about the actual contribution of *music theory journals* to *music and memory* research between *2020 and 2025* in the JSTOR database.

The distribution in *Figure 3b* confirms that *music cognition* and *theory* research is strongly concentrated in *Music Perception (MP)*, with limited contributions from journals such as *Contributions to Music Education (CME)*, *College Music Symposium (CMS)*, *Music Educators Journal (MEJ)*, and *Indiana Theory Review (PITR)*. This pattern indicates a *disciplinary silo* and a persistent lack of *structural music theory* perspectives in broader *interdisciplinary* and *clinical outlets* concerned with *music and memory*. The first major implication is that there is a substantive need to extend rigorous *music-theoretical approaches* into *cognitive* and *health science* contexts.



(a) Journal distributions on PubMed and JSTOR.



(b) Journal distribution filtered for music cognition and theory.

Figure 3: Journal distribution analysis.

Focusing on the *Background Code* legend in Table 1 and the distributions in *Figure 4* clarifies how *music* and *health sciences* research is organized around key thematic areas. In *Health Sciences*, the largest cluster is *"Non-Pharmacological Interventions"* (69 articles),

while in *Music* the leading background is *"Autobiographical Music Memory"*. *Musical expertise* and *cultural memory* appear across both domains. This configuration suggests strong potential for leveraging *autobiographical* and *cultural dimensions* of music to address pressing needs in *dementia* and *Alzheimer's* research. However, research categorized under *"Technological Tools for Dementia Care"* remains rare—appearing only once in the music domain and scarcely in health sciences—despite its clear relevance. This scarcity anticipates one of the central issues highlighted later in the *Goal* distributions: the need for dedicated technological infrastructures for music–memory studies.

Table 1: Background categories in music and dementia research

Code	**Category Name**	**Description**
0	Autobiographical Music Memory	Studies focusing on how music evokes autobiographical or emotional memories, the cognitive processes involved, and the neural mechanisms that link familiar music to personal memory.
1	Music Therapy for Mild Cognitive Impairment	Research addressing therapeutic uses of music for people with mild to moderate cognitive decline (e.g., early Alzheimer's), emphasizing physical activity and cognitive stimulation.
2	Technological Tools for Dementia Care	Studies exploring mobile apps, assistive technologies, and digital interventions designed to help manage dementia or other chronic conditions.
3	Non-Pharmacological Interventions	Research comparing non-drug interventions like music therapy with pharmacological treatments for managing symptoms in dementia and Alzheimer's.
4	Social and Psychosocial Well-being	Studies highlighting how music impacts social interaction, caregiver support, and psychosocial well-being for people with dementia and their families.
5	Musical Expertise and Cultural Memory	Research exploring working memory for music, cultural aspects of musical remembrance, or studies on musical expertise and its cognitive correlates.

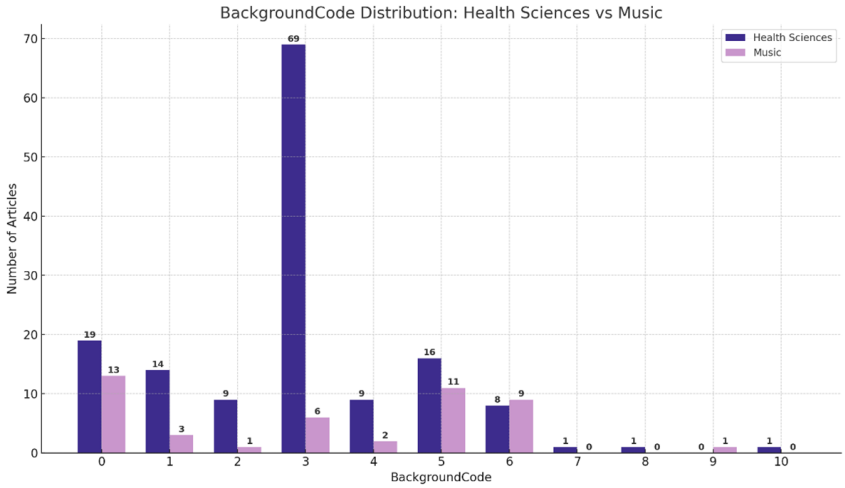


Figure 4: Distribution of background categories in research.

The *Problem Code* distribution in *Figure 5* highlights key priorities and gaps in *dementia* and *memory* research across *Health Sciences* and *Music*. In both domains, the most prominent category is *"Lack of Evidence"*: 83 articles in Health Sciences and 16 in Music, indicating a strong demand for robust, scalable data and *real-time measurement tools*. *"Cognitive Challenges"* form the second largest cluster, reflecting shared concern with severe decline but differing disciplinary approaches. *"Pharma/Medical"* limitations in Health Sciences underscore the search for *non-drug options*. In Music, *"Cultural & Reminiscence"* is relatively stronger, while *"Music Understanding"* remains smaller in volume but crucial for bridging *music theory* and applied research.

Notably, categories such as *"Neural & Sensory"* and *"Tech & Implementation"* are underrepresented in both *Health Sciences* and *Music*, pointing to a persistent *technology gap*. Existing studies recognize earlier contributions but repeatedly call for tools that can more precisely capture and model *music's non-pharmacological effects*, as subsequently reflected in the *Goal* distributions. This constellation of problems motivates the present work: the development of *technology* designed to strengthen *Music Understanding*, address *Lack of Evidence*, and advance *Tech & Implementation* by connecting *music-theoretical* perspectives with *real-time neurocognitive validation* in *music and memory* research.

Table 2: Problem legend

Code	Problem Category	Description
0	Lack of Evidence	Lack of robust data or the presence of basic research gaps.
1	Non-Pharmacological	Music/non-drug interventions including therapy effectiveness.
2	Cognitive Challenges	Cognitive decline, severe stage difficulties.
3	Caregiver & Social Well-being	Caregiver burden, social and psychosocial impacts.
4	Tech & Implementation	Technological gaps and implementation barriers.
5	Cultural & Reminiscence	Cultural gaps, reminiscence/autobiographical music.
6	Music Understanding	Perception, notation/analysis, everyday musical phenomena.
7	Neural & Sensory	Neural mechanisms, sensory/motor synchronization.
8	Ethics & Society	Ethical dilemmas, social issues.
9	Pharma/Medical	Pharmacological limitations.
10	Environmental	Environmental and navigation factors.
11	Cultural Politic	Neglect of certain genres in cultural memory.

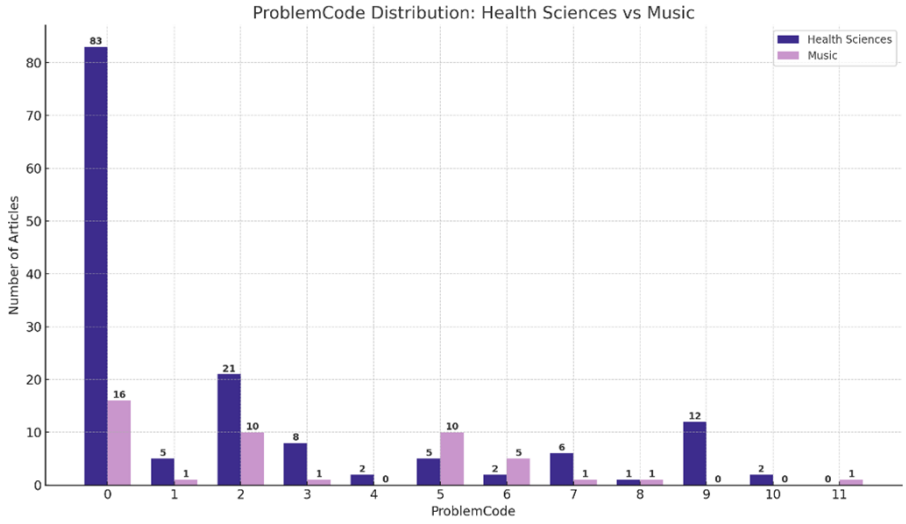


Figure 5: Distribution of problem categories in research.

Using the *Goal Category* legend in Table 3, the *Goal Code* distribution in *Figure 6* clari-

fies how *music and memory* research formulates its aims as an extension of the identified backgrounds and problems. In *Health Sciences*, the most frequent goal is *"Develop Technology or Tools / Improve Understanding of Memory"* (52 articles), revealing a strong emphasis on designing technical systems and digital tools to monitor memory decline and assess music's cognitive impact. This focus directly corresponds to the *evidence gaps* and *technology gaps* discussed above.

The next most common goals—*"Psychological Mechanism Study"* (36 articles) and *"Therapeutic Application"* (27 articles)—underline the field's effort to understand how music influences perception, emotion, and cognition as a basis for evidence-based interventions. This progression suggests a coherent logic: the development of robust tools enables deeper psychological insight, which in turn supports more precise therapeutic design.

Additional goal clusters such as *"Raise Awareness / Advocacy"*, *"Practical Guidelines Development"*, and *"Pilot / Feasibility Testing"* indicate growing interest in translating research into clinical practice and public awareness. Less frequent but conceptually important goals—*"Neural Mechanisms Exploration"*, *"Cognitive Neuroscience Validation"*, and *"Clinical Practice Model Development"*—point to emerging attempts to integrate theoretical constructs with neurological and clinical implementation.

In the *music* domain, the leading goal mirrors that of Health Sciences: *"Develop Technology or Tools / Improve Understanding of Memory"* (19 articles). The present research aligns directly with this goal by introducing a software environment that integrates *functional Roman numeral analysis* of musical structure with *facial expression* and *EEG* signals. This system generates *real-time, multimodal data* that addresses critical gaps in the field by advancing *Music Understanding*, enabling *neural validation* of musical processes, and providing *practical guidance* for future music–memory studies.

The category *"Develop Technology or Tools / Improve Understanding of Memory"* is followed by *"Historical or Cultural Analysis"*, *"Psychological Mechanism Study"*, and *"Therapeutic Application"*. Smaller yet meaningful contributions in *"Practical Guidelines"*, *"Social / Emotional Impact"*, and *"Neural Mechanisms"* hint at promising pathways for inte-

grating traditional music-theoretical approaches with applied therapeutic frameworks.

Table 3: Goal legend

Code	Goal Category Name	Description
0	Develop Technology or Tools / Improve Understanding of Memory	Goals focused on creating new technical systems, algorithms, instruments, or digital tools for music, and on testing, modelling, or extending theories of memory in relation to music listening or recall.
1	Historical or Cultural Analysis	Analyses of music's role in cultural, historical, or social contexts and memory across time periods.
2	Psychological Mechanism Study	Investigations of perceptual, cognitive, or emotional processes linked to music, memory, or wellbeing.
3	Raise Awareness / Advocacy	Uses of music or music studies to raise awareness for social, medical, or community issues (e.g., dementia).
4	Therapeutic Application	Development or testing of therapeutic interventions using music for health, emotional, or cognitive benefits.
5	Practical Guidelines Development	Structured playlist guidelines or protocols for dementia and related conditions.
6	Pilot/Feasibility Testing	Small-scale preliminary studies that assess feasibility and refine protocols before large trials.
7	Social/Emotional Impact	Studies of singing-based or other musical interventions on social and emotional states.
8	Neural Mechanisms Exploration	Work on non-invasive brain engagement via music.
9	Cognitive Neuroscience Validation	ERP or related analyses probing links between musical syntax and cognitive processes.
10	Clinical Practice Model Development	Design of clinical practice models and frameworks for therapists.

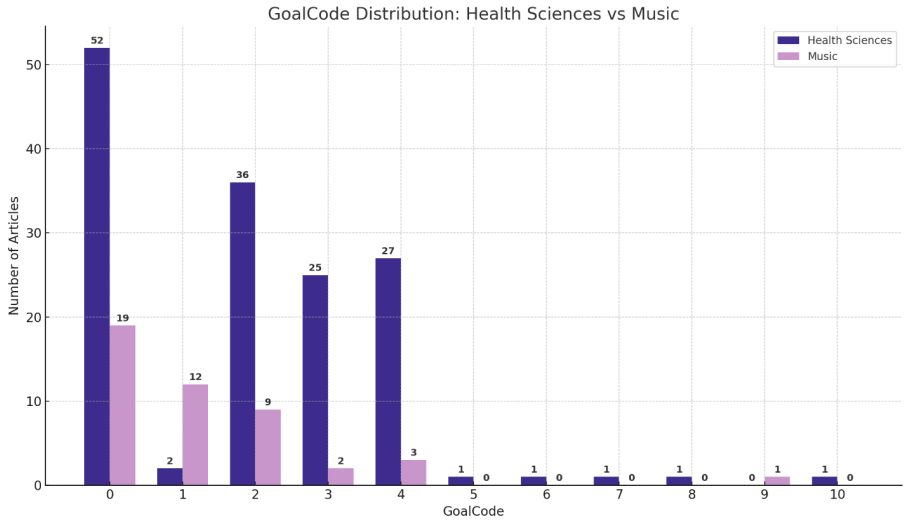


Figure 6: Distribution of goal categories in research.

Building on the *Method Code* legend in Table 4, the distribution in *Figure 7* shows how *music and memory* research approaches *evidence generation*. In *Health Sciences*, the most frequent method is the *Longitudinal Cohort* design (28 studies), indicating substantial investment in tracking patient change over time—crucial for understanding the progression of *dementia*. *Survey / Psychometric Assessment* and *Randomized Controlled Trials (RCT)* also appear prominently, underscoring an emphasis on repeated measurement and rigorous *clinical testing*.

Categories such as *Experimental Intervention* and *Clinical Measurement / Physiological Recording* reflect direct, lab-based *evidence collection*, including *EEG* and other biomarkers. *Pilot Study Design* and *Clinical Guideline Development* mark efforts to evaluate feasibility and translate findings into practical frameworks. *Observational Review* and *Secondary Data / Meta-Analysis* demonstrate the ongoing importance of synthesis and foundational mapping.

In *Music*, the pattern is different: the largest share comprises *Experimental Intervention* and *Survey / Psychometric Assessment*, indicating reliance on *small-scale interventions* and *perception testing*, with comparatively fewer *longitudinal* and *physiological* studies. The relatively rare use of *Structured Musical Performance Task* and *Neural Mechanisms* methods reveals an emerging yet underdeveloped link between *music theory* and *cognitive*

validation.

Overall, current research strongly emphasizes the benefits of *music* as a *non-pharmacological* intervention but often lacks sufficiently detailed *analytical tools* to explain how specific musical structures produce these effects. This has encouraged the development of new *technologies* and *methods*, yet a methodological gap remains: repeatedly applying the same traditional approaches risks generating *repetitive results* and *limited insights*.

If the central object of study is *music*, then the ways in which we *classify*, *segment*, and *analyze musical material* become critical. How music is divided into *meaningful units* and mapped onto *behavioral* and *neurophysiological* data directly shapes the depth and interpretability of findings. Without updating these *classification* and *tokenization methods*, the field risks a cycle in which familiar methods repeatedly yield familiar conclusions, constraining innovation.

Consequently, it is essential to examine how research in *Music* and *Health Sciences* categorizes *musical parameters* and to assess whether these approaches support the development of *new tools* capable of advancing *music and memory* research in a structurally informed way.

Table 4: Method legend

Code	Method Category	Description
0	Observational Review	Theoretical studies, literature reviews, or conceptual analyses that do not collect new empirical data but map existing findings and frameworks.
1	Experimental Intervention	Active interventions (e.g., music therapy sessions, new tools, experimental tasks), typically with pre–post or group comparison designs.
2	Survey / Psychometric Assessment	Self-report measures, questionnaires, scales, or cognitive tests assessing perception, memory, or well-being.
3	Qualitative Interview / Case Study	In-depth interviews, focus groups, or detailed case studies exploring personal experience and context.
4	Clinical Measurement / Physiological Recording	EEG, ERP, fMRI, or other physiological measures linking musical tasks to brain, sensory, or motor responses.
5	Pilot Study Design	Small-scale preliminary studies testing feasibility and refining protocols.
6	Structured Musical Performance Task	Controlled tasks (e.g., singing, instrumental performance, rhythm/melody tasks) examining specific cognitive or motor outcomes.
7	Randomized Controlled Trial (RCT)	Randomized intervention/control designs serving as a gold standard for clinical evidence.
8	Secondary Data / Meta-Analysis	Reuse of existing datasets or combination of multiple studies to generate higher-level insights.
9	Longitudinal Cohort	Studies following the same participants over time with repeated measures.
10	Clinical Guideline Development	Design of practical frameworks, protocols, or models for real-world clinical practice.

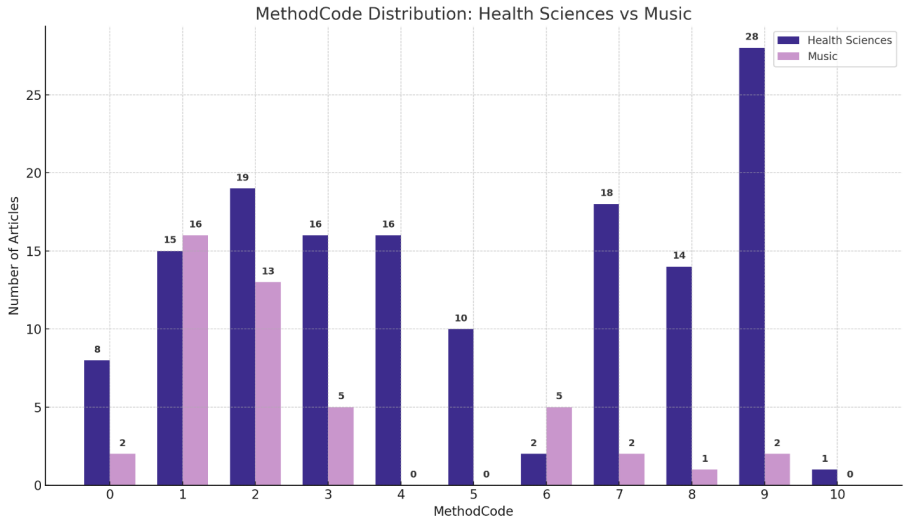


Figure 7: Distribution of method categories in research.

Using the *HowMusicCategorizedCode* legend in Table 5, the distribution in *Figure 8* clarifies how research in *Health Sciences* and *Music* classifies its musical material. In *Health Sciences*, the dominant category is *"Rehabilitation Therapy / Music Memory Recall"* (104 studies), underscoring strong *biomedical interest* in *music as a therapeutic tool* to stimulate memory in *dementia* and *Alzheimer's* contexts and aligning closely with *non-pharmacological* clinical needs.

Smaller but notable clusters, such as *"Cognitive Load"* and *"Performance Practice"*, show that some studies examine *mental effort* and *musical performance* in relation to cognitive decline. However, codes such as *"Neural Mechanisms"*, *"Musical Structure"*, and *"Tempo Memory"* are underrepresented, suggesting that while the therapeutic uses of music are extensively investigated, the underlying *structural* and *neurophysiological* frameworks receive comparatively less systematic attention.

In *Music*, the leading focus is again *"Rehabilitation Therapy / Music Memory Recall"*, but with fewer studies overall. Here, categories such as *"Musical Structure"*, *"Performance Practice"*, and *"Social Interaction"* occupy a relatively larger share, indicating that *music scholars* tend to engage more deeply with the *structural* and *social* dimensions of *music* as they relate to *cognition* and *wellbeing*.

Table 5: How music categorized legend

Code	Category	Description
0	Tempo Memory	Studies on musical tempo memory, accuracy, and temporal cognition.
1	Cognitive Load	Focus on cognitive load, attention, and mental effort in music tasks.
2	Rehabilitation Therapy / Music Memory Recall	Therapeutic applications of music for rehabilitation and memory recall processes triggered by familiar music.
3	Performance Practice	Research on performance practices and the execution of music.
4	Social Interaction	Studies of music's role in social interaction and communication.
5	Music and Language	Work on relationships between music and language processing.
6	Neural Mechanisms	Research on neural mechanisms and brain activity related to music perception.
7	Musical Structure	Studies involving musical structure and analytical frameworks.

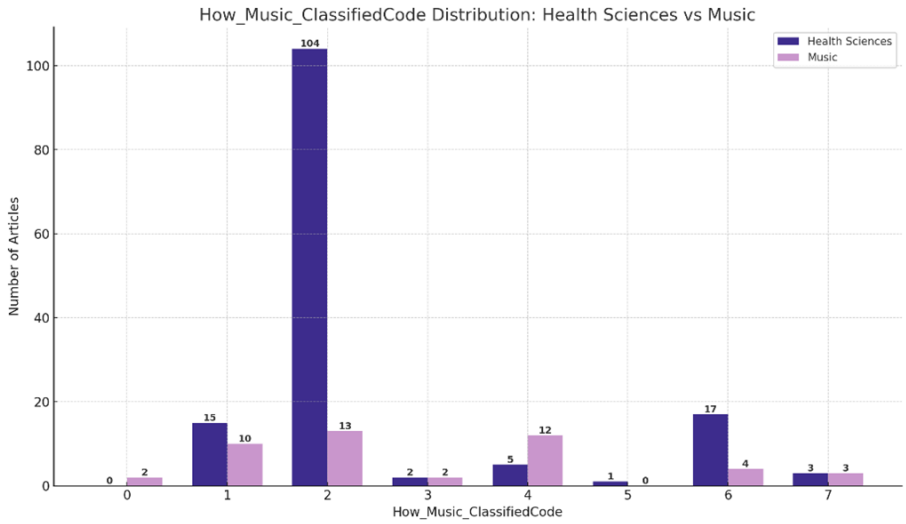


Figure 8: Distribution of "How music is categorized" in research.

At this point, a central question of this *data analysis* emerges: to what extent does the *music classification* in Table 5 reflect genuinely *structural*, *harmonic*, or *melodic* theoretical categorization? *Figure 9* demonstrates that *Health Sciences* overwhelmingly neglects

structural music analysis: 98% of its articles include no *harmonic* or *melodic* analysis, indicating that *therapeutic uses of music* rarely incorporate detailed *structural investigation*. In *Music*, the situation is somewhat better but still limited: approximately 69.6% of studies do not include structural analysis, while about 30% employ *harmonic*, *melodic*, or combined approaches.

This pattern reveals a major opportunity: Current *clinical research* largely overlooks how *real-time structural elements* —such as *harmony* and *melody*—shape *memory* and *brain responses*. Without this structural layer, interventions risk remaining relatively coarse and descriptive.

The main proposal of this work therefore becomes clear: just as *cognitive linguistics* relies on discrete *grammatical categories*, *music cognition* and *music–memory* research must *tokenize music* into *structural units*—*harmonic*, *melodic*, or combined—in order to link *musical structure* with *cognitive* and *neural processes* in a principled way. Without such tokenization, the field risks recurrent *broad generalizations* that overlook how *music's internal grammar* interacts with the *brain*.

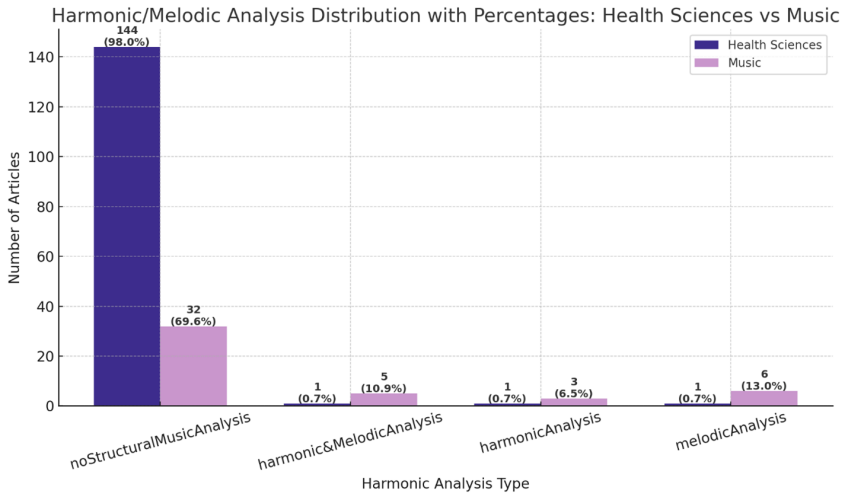


Figure 9: Distribution of harmonic/melodic analysis categories in research.

The analysis next turns to the 17 studies that explicitly apply *structural music analysis* within *music and memory* research. *Figure 10* shows that most of this work appears in the *Music* domain, with a smaller share in *Health Sciences*. This suggests that *structural music analysis* remains predominantly situated in *musicology* and *theoretical studies*, even

though some research does reach into *health sciences*, indicating genuine *interdisciplinary* attempts to connect *musical structure* with *therapeutic* or *cognitive health* questions.

Figure 11 demonstrates that studies involving *harmonic and melodic analysis* span several *specific fields*, with *music cognition/theory* and *musicology* forming the dominant cluster. A smaller but notable portion comes from *Neuroscience*, pointing to an *interdisciplinary extension* in which *structural music features* are investigated for their *cognitive* and *neural* implications. At the same time, although *behavioral studies* account for 107 publications (approximately 72.79%), none of the *behavioral science* articles incorporate *structural music analysis*, highlighting an important but unresolved question about why structural methods remain so rarely integrated in this subfield.

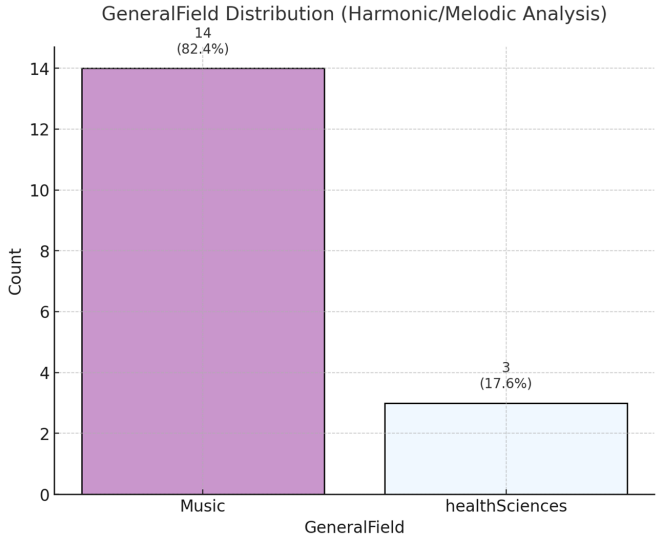


Figure 10: General field distribution (filtered for harmonic/melodic analysis).

Taken together, these findings suggest several important points. Although the volume of publications in *Health Sciences* is considerably higher, *music* studies employ *structural music analysis* more frequently when addressing *music and memory*. This indicates that music–memory research within the *music discipline* tends to draw on its *core expertise* in structural analysis, whereas the integration of the *memory component*—typically examined in *health sciences*—with *music structure* remains largely unresolved. Moreover, even within music-domain studies of *music and memory*, 69.6% do not apply structural analysis, which makes it less surprising that 98% of *health-science* studies in this area

also omit such analysis. This pattern underscores the need for stronger *collaborative* and *interdisciplinary* frameworks. As noted above, this gap is likely rooted in the limited incorporation of *music theory* into *music and memory* research, despite music theory being uniquely equipped to supply detailed structural descriptions.

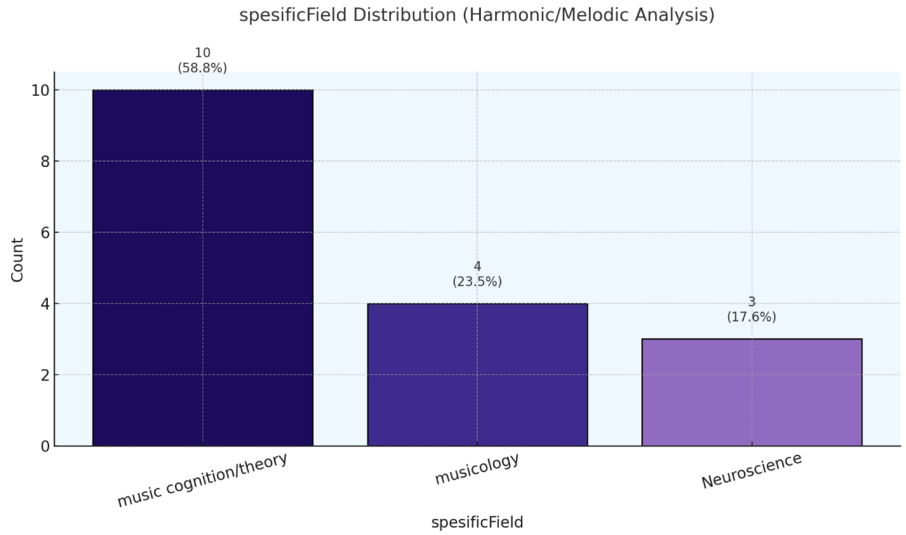


Figure 11: Specific field distribution for studies using harmonic/melodic analysis.

The remainder of this section filters prior research to identify those studies most closely aligned with the *system* and *aims* developed here. By focusing on this subset, it becomes possible to examine their *methods*, *focus areas*, and *findings* in greater detail, and to clarify how the *memory component* is integrated with *musical structure* in existing work. These studies also provide a basis for comparing and contrasting the proposed *tools* and *framework* with current practices.

First, three studies in *Health Sciences* explicitly integrate a form of *structural music analysis* within *neuroscience*. The *M4M study* [Lichtensztein et al., 2024] adopts a basic structural strategy by composing new songs that incorporate familiar formal components (*verses*, *choruses*, *cadences*) to support learning in participants with *Alzheimer's disease*. This predefined structure is embedded in an individualized, singing-based pedagogical intervention designed to reinforce *musical semantic memory*. The study further employs *EEG* to assess neural responses to *in-key violations* within the learned melodies, using these tonal deviations as controlled stimuli to distinguish between *memory-based* and *rule-*

based cognitive processes, as indicated by the *N400* component. However, the approach does not constitute a comprehensive *music-theoretical analysis*; rather, formal structure is used in a pragmatic way (e.g., Verse 1, Verse 2, Chorus, repetitions, final cadence) to probe neurocognitive mechanisms. Moreover, while *EEG* is recorded during listening, there is no *real-time software* for dynamic alignment between musical events and neural data; analyses are conducted *offline*, which limits temporal precision in stimulus–brain correspondence.

[Derks-Dijkman et al., 2024] offers a review of studies that use basic musical structures—such as *rhythm*, *pitch patterns*, and *melody*—to examine the effects of sung versus spoken presentation on *memory performance*. These studies typically use simple, tightly controlled musical stimuli (e.g., *digit sequences*, *rhymed verses*, *novel lyrics*) to assess the efficacy of *musical mnemonics* for *working* and *episodic memory* in cognitively unimpaired older adults and individuals with *Alzheimer's disease*. While these components function as *structural prompts* to support recall, the review makes clear that they are used primarily as *experimental stimuli* rather than being subject to *music-theoretical analysis*. This underscores a continuing gap between experimental design in cognitive research and the analytical depth of formal music theory.

[Benhamou et al., 2021] incorporates a more explicit *structural music analysis* by manipulating *acoustic*, *syntactic* (*key-violating*), and *semantic* (*key-preserving*) changes in *familiar melodies* to study *expectation* and *surprise* in *dementia*. An *information-theoretic model* is used to quantify *musical entropy* and *surprise*, which are then linked to *behavioral*, *physiological*, and *neuroanatomical* measures.

Taken together, two of the three studies [Benhamou et al., 2021, Lichtensztein et al., 2024] employ *structural music analysis* by deliberately designing *tonal* or *melodic rule violations*, or by composing songs with clear *formal structures*, to investigate *expectation*, *memory*, and *cognitive responses* in *dementia*. Their shared aim is to experimentally probe how *rule-based prediction mechanisms* in music relate to *neurophysiological* and *behavioral* measures. The *tool* developed in this work is conceived as a *software environment* that can

synchronize and *automate* similar research paradigms in real time.

The analysis then turns to *music studies* more broadly to clarify how they approach *music and memory* and, in particular, how the *memory component* is conceptualized within the field of *Music*. Among *musicological* work, four studies illustrate how music contributes to preserving and reshaping *collective memory*. *Julia Escribano Blanco*'s *Cataloguing of Traditional Music* documents extensive *field recordings* from rural *Soria*, which are structurally transcribed and classified by *function* and *form*, yielding a *searchable digital archive* that conserves regional musical structures for *ethnomusicological* research [Escribano Blanco, 2025]. *Halina Goldberg*'s work on *Chopin's Album Leaves* explores how short autograph pieces, created for *19th-century keepsake albums*, encode memory via *miniature musical structures* that combine *private reflection* and *cultural inscription* [Goldberg, 2020]. *Burcu Yıldız*'s study of *Transcultural Memory in the Study of Folk Music in Turkey* examines early *diaspora 78-rpm recordings*, showing how these performances preserve *modal frameworks (makam)* and multilingual layers that challenge *nationalist narratives* and foreground the *structural complexity* of folk music [Yıldız, 2024]. Finally, *Carina Venter*'s analysis of *Steve Reich's Different Trains* demonstrates how *structural repetition* and the layering of speech and string quartet textures construct a *sonic documentary* intertwining *personal autobiography* with the *collective memory* of the *Holocaust* [Venter, 2021]. While these studies offer rich accounts of the *autobiographical* and *cultural* dimensions of music in relation to long-term individual and collective memory, they operate outside the *therapeutic* and *AI-assisted* contexts that are central to the present work and are therefore considered out of scope for the system-focused analysis.

The remaining ten key studies in *music cognition* and *theoretical research* employ *structural music analysis* in ways that more directly inform the present project. [Miller, 2021] uses structural analysis to show how *Schubert's measure 154* functions as a *"punctuation chord"*, linking *formal sections* and revealing a hidden palindromic structure in the *String Quintet in C Major*. [Killingly et al., 2021] describe *earworms* as arising from *involuntary mental repetition* of simple melodic patterns that occupy *working memory*. [Kurzom et al., 2025] design musical segments with varying levels of *harmonic tension* to test how tonal tension

influences *spoken word memory*.

As in the neurophysiological work noted earlier, [Lichtensztein et al., 2024] composes new songs with clear *formal sections* and tests *in-key violations* using *EEG* to examine *memory* and *rule-based processing* in *Alzheimer's* patients, while [Benhamou et al., 2021] manipulates *acoustic*, *syntactic*, and *semantic* aspects of familiar melodies to study *expectation* and *surprise* in dementia via an *information-theoretic* model. In *music cognition* and *theory*, [Goldman et al., 2021] re-examines *EEG responses* to unexpected chords in popular music, further extending this line of inquiry. Although all three studies rely on *structural alignment*, they perform analysis *offline* rather than in real time. The *system* proposed here addresses this limitation by *synchronizing musical structure* with *electrophysiological* data in *real time*.

In *behavioral* research, [Byron et al., 2025] analyzes how *hooks* in pop songs influence *listener attention* and *memory*—an area where the proposed system can provide more precise and scalable measurements. [Telesco et al., 2021] demonstrates that *retrieval practice* strengthens pianists' memory for *short melodies*, building on [Goldman, 2016]'s work on *action–perception coupling*.

Regarding *short-term and long-term memory*, [Kubit et al., 2025] shows that *repetition* can transform *speech into song* via *phrase learning* and long-term memory, while decoupling memory from attention. [Jimenez et al., 2022] compares *veridical* and *schematic harmony memory* in familiar pop songs, directly linking short- and long-term harmonic memory. [Weiss and Peretz, 2024] segment melodies into *interval* and *contour* units to demonstrate how *pitch direction* and *interval size* affect recall, and [Loutrari et al., 2022] divide songs into *phrases* to study *pitch imitation* and *amusia*. Together, these four studies address complementary aspects of short- and long-term musical memory—domains that the proposed *system* seeks to integrate and test within a unified digital framework.

Overall, this body of work shows how *structural features* shape *cognition*, *prediction*, and *memory*. Building on these insights, the present project proposes a *real-time*, *automated framework* that aligns *musical structure* with *behavioral* and *neural* data, thereby advanc-

ing research at the intersection of *music theory*, *cognition*, and *computational modelling*.

Finally, the analysis returns to the coded dataset of outcomes and conclusions. Based on the *Results Category* legend in Table 6, the distribution in *Figure 12* reveals how *study outcomes* are framed. In *Health Sciences*, the dominant category is *"Memory Improvement"* and related *General Cognitive & Rehabilitation* outcomes, followed by *Social & Behavioral Outcome* and *Emotional & Learning Effect*, indicating a priority on *tangible, measurable* benefits for people living with dementia. Smaller but meaningful shares in *Brain Mechanism* and *Motor & Executive Function* highlight ongoing work on mechanistic and functional aspects of music-based interventions. In *Music*, results lean toward *Music Practice & Perception* and selected *Cognitive* or *Emotional* effects, but with considerably fewer studies overall, suggesting that music-domain scholarship still tends to focus on perception and relatively modest cognitive shifts rather than large-scale behavioural or physiological endpoints.

Table 6: Results legend

Code	Results Category Name	Description
1	Brain Mechanism	Combined cognitive, neural, biomarker, and feasibility outcomes, including smaller mechanistic and methodological studies.
2	Sleep and Circadian	Sleep, circadian rhythm, and melatonin-related findings.
3	Memory Improvement	Direct findings on memory enhancement and recall.
4	Neurodegeneration	Outcomes focused on Alzheimer's disease and related neurodegenerative mechanisms.
5	Motor & Executive Function	Motor skills, coordination, and executive function improvement.
6	Emotional & Learning Effect	Combined emotional, mood, and learning-related outcomes.
7	Social & Behavioral Outcome	Combined social interaction, behavioural change, and health-impact findings.
8	Music Practice & Perception	Combined music performance, practice, and perception outcomes.
9	General Cognitive & Rehabilitation	Cognitive rehabilitation, general cognitive benefit, and decline-prevention outcomes.

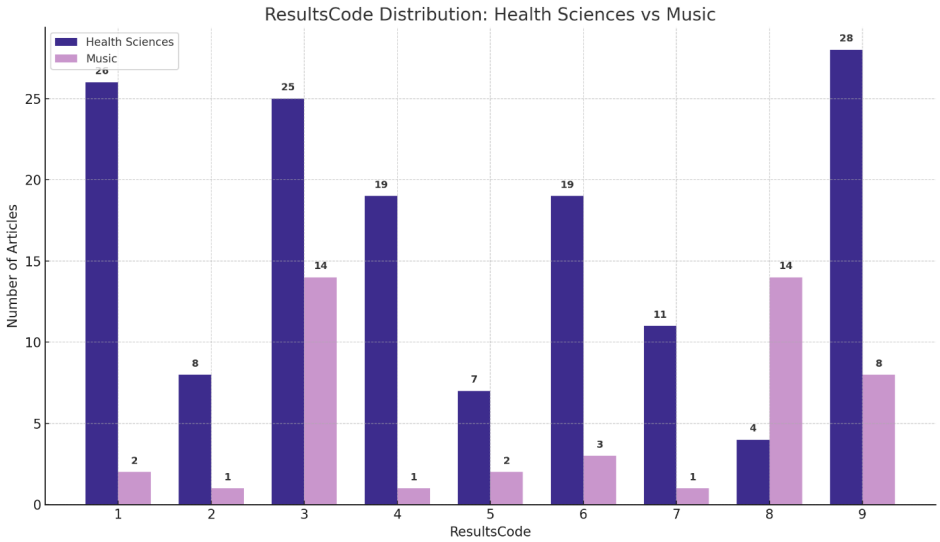


Figure 12: Distribution of results categories in research.

Finally, using the *Conclusion Category* legend in Table 7, *Figure 13* shows how *Health Sciences* and *Music* differ in their concluding emphases. In *Health Sciences*, the most frequent conclusions fall under *"General Music Benefits"*, *"Therapeutic Mechanism Insights"*, and *"Broader Quality of Life Impacts"*, reflecting attention to broad wellbeing, foundational evidence, and intervention-related mechanisms. Categories such as *"Program Feasibility & Acceptance"* and *"Recruitment & Inclusion Challenges"* underscore practical concerns around implementation and study design. In *Music*, conclusions tend to emphasize *"Musical Memory & Training"*, *"Historical Treatise Validation"*, and selected *Therapeutic Mechanism* insights, but with fewer studies addressing feasibility or recruitment directly.

Taken together, the current literature outlines clear benefits and plausible mechanisms for *music and memory* interventions but still lacks an *automated-expert-level music analysis* environment capable of *advanced music tokenization* and *integrated multimodal alignment*. To move beyond largely conceptual conclusions and address persistent gaps in *music and memory* research—especially in the context of urgent therapeutic needs for people with *dementia* and *Alzheimer's*—it is essential to combine detailed *structural analysis* with *behavioral* and *neuroscientific* data in *real time*. The system proposed in this work is designed to contribute precisely such an integrated framework.

Table 7: Conclusion legend

Code	Conclusion Category Name	Description
0	Program Feasibility & Acceptance	Conclusions confirming program feasibility, acceptance, and practical implementation outcomes.
1	Historical Treatise Validation	Conclusions validating historical or theoretical sources related to cognitive or musical practice.
2	General Music Benefits	General conclusions about broad benefits of music on health, cognition, and well-being.
3	Recruitment & Inclusion Challenges	Discussions of patient recruitment, inclusion criteria, and feasibility of study designs.
4	Musical Memory & Training	Findings focused on musical memory accuracy, tempo training, and skill stability.
5	Therapeutic Mechanism Insights	Insights into specific therapeutic mechanisms, dosage, or personalization of interventions.
6	Broader Quality of Life Impacts	Evidence for music's wider impact on quality of life, daily functioning, and social context.

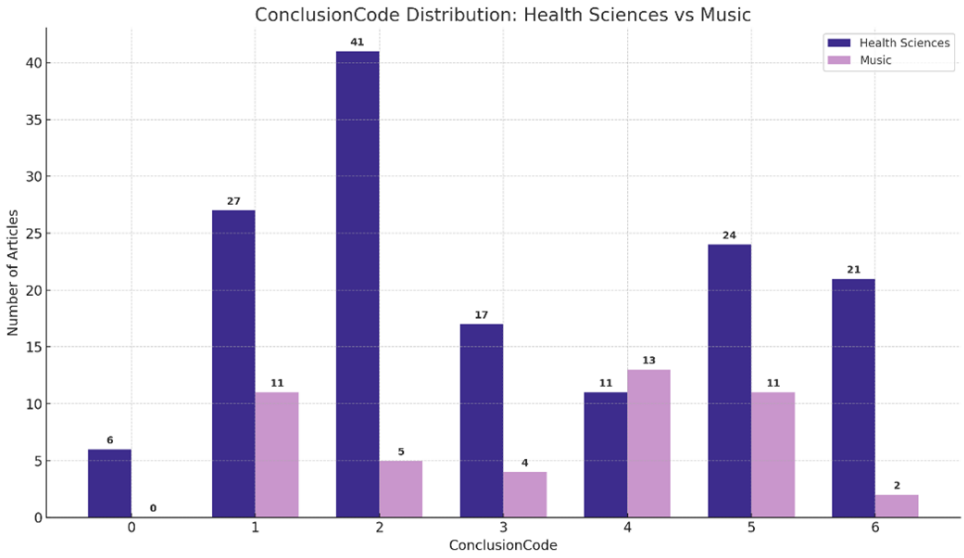


Figure 13: ConclusionCode distribution: Health Sciences vs. Music.

2.1 Conclusion of Data Analysis Part 1

Three key insights and a central proposition emerge from this analysis. First, between *2020 and 2025*, major *music theory journals* in the *JSTOR database* have made very limited contributions to *music and memory research*. As a result, the role of *structural*

music analysis remains largely absent in *health sciences* and continues to be relatively constrained even within *music scholarship* itself. This situation appears to be associated with the lack of *integrated tools and software* capable of synchronizing and automating *musical*, *behavioral*, and *electrophysiological parameters*. The main argument of this study is that developing a comprehensive understanding of how *memory functions in music* requires an *integrated technological environment* that connects these modalities. At this point, it becomes essential to consider whether current research provides *computational models* that can segment music into discrete units, forming the technological foundation necessary for advancing *music and memory research*.

3 Data Analysis Part 2: Current State-of-the-Art Technologies in Automatic Music Analysis

Data Analysis Part 2 provides a structured overview of recent developments in *chord recognition* and *music tokenization* across major academic databases. The comparative distribution indicates that *arXiv* currently leads in publication volume, reflecting the prominence of open-access dissemination in *computational music research*. *IEEE* maintains a steady trajectory with engineering-oriented contributions, while *TISMIR* offers a specialized subset grounded in *music information retrieval*. When broken down by analysis type, *automatic chord recognition* remains the dominant approach; however, *manual expert annotation*—especially in the form of *Roman numeral analysis*—continues to play a central role in training, validating, and benchmarking these systems. This confirms the ongoing importance of *functional harmony* as both a theoretical construct and an empirical reference point for the field. As a precursor to the system introduced later in this thesis, these visualizations contextualize *Roman numeral analysis* not only as a tokenization method but also as a cognitively meaningful, musically interpretable representation for the advancement of *music AI*.

Figure 14 summarizes the distribution of studies on *"chord recognition"* and *"music tokenization"* across *arXiv*, *IEEE*, and *TISMIR*. *arXiv* contains the largest proportion of pub-

lications, reflecting strong interest in *open-access computational music research*. *IEEE* follows with consistent, engineering-focused contributions, while *TISMIR* provides a smaller but highly specialized segment of the literature.

Figure 14: Database Distribution for “chord recognition” and “music tokenization” Research.

Figure 15 tracks publication trends from *2020 to 2025*. *arXiv* shows steady activity with slight growth, underscoring its role in early-stage and experimental research. *IEEE* maintains dependable contributions from the engineering community, while *TISMIR*, though smaller in scale, remains a stable venue for specialized *MIR* studies.

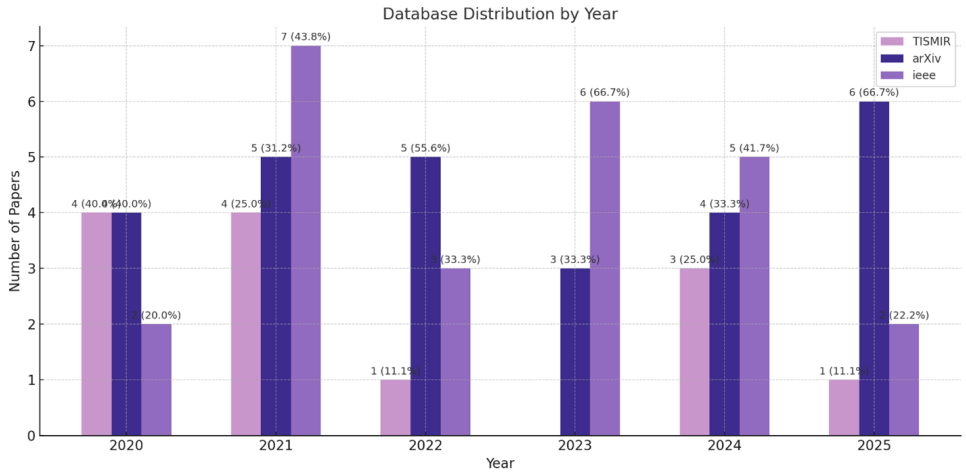


Figure 15: Database Distribution by Year for Chord Recognition and Music Tokenization Related Studies.

Figure 16 presents the distribution of analysis types—namely *automatic chord recognition*, *manual expert annotation*, and cases with *no chord analysis*. Most works prioritize *automatic recognition*, reflecting the field's reliance on algorithmic tools. Nonetheless, *manual annotation* retains a significant presence, underscoring the need for expert-curated data in developing and assessing computational models. A smaller subset consists of studies addressing related topics without direct chord analysis.

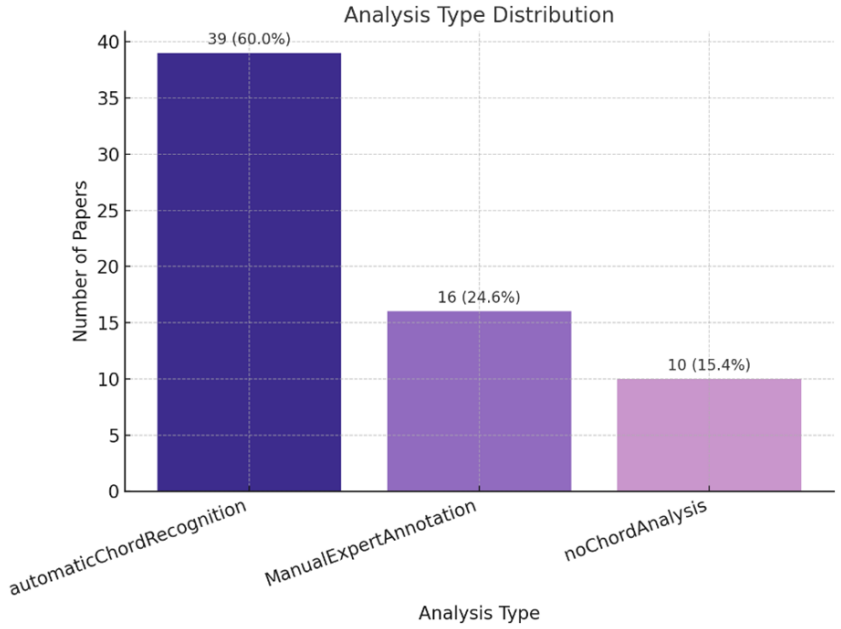


Figure 16: Analysis Type Distribution for "chord recognition" and "music tokenization" Research.

Crucially, the system proposed later in this thesis adopts *Roman numeral analysis* as its primary tokenization strategy, conceptualizing *Roman numerals* as approximate analogues of musical "words." Whereas *chord labels* identify surface-level pitch-class content (e.g., *C major*, *G7*) without accounting for musical context, *Roman numeral analysis* situates chords within a tonal framework, emphasizing *harmonic function* and *progressional relationships*. This approach yields a deeper representation of *tonal structure* that aligns more closely with the *cognitive foundations* of musical perception. For this reason, the remainder of this analysis foregrounds works involving manually or automatically derived *Roman numeral analyses*.

Figure 17 displays the distribution of *manual expert annotations*. Most studies rely on *Chord Labels*, reflecting their accessibility and suitability for training and evaluation tasks. *Roman numeral analysis* represents more than one-third of the annotations, demonstrating strong scholarly interest in functional harmony. A smaller proportion employs detailed *note-level parts* such as *Root*, *Bass*, or *Soprano*.

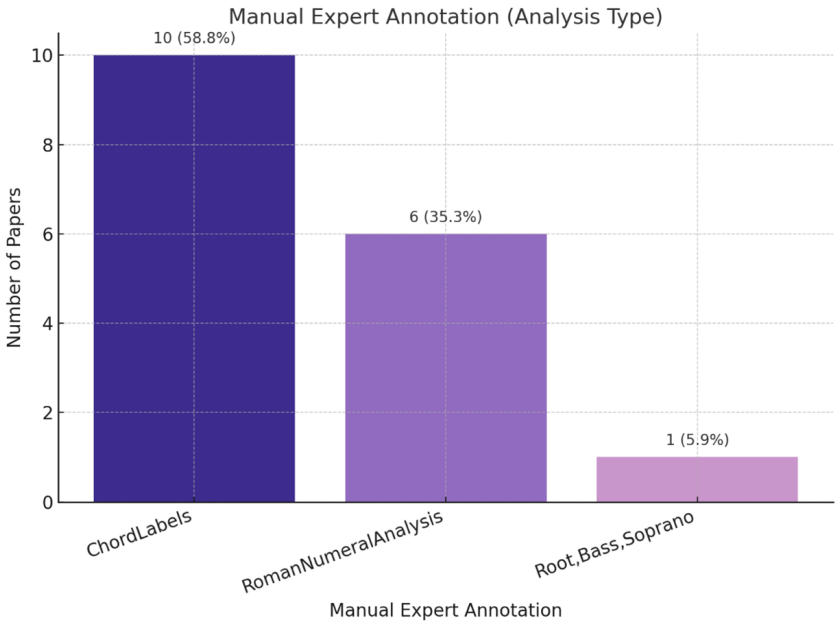


Figure 17: Distribution of Manual Expert Annotation Type for "chord recognition" and "music tokenization" Research.

To establish a benchmark for the proposed system, this section examines six representative works spanning major directions in symbolic music research. *Attend to Chords*

[Chen and Su, 2021], *Not All Roads Lead to Rome* [Micchi et al., 2020], and *Melody Transcription via Generative Pre-Training* [Donahue et al., 2022] introduce machine learning systems for chord recognition, Roman numeral analysis, and melody transcription, frequently using Transformer-based architectures guided by expert-annotated datasets. *BPSD* [Zeitler et al., 2024] and *The Annotated Mozart Sonatas* [Hentschel et al., 2021] contribute high-quality, expert-labeled datasets, while *Using Note-Level Music Encodings* [Devaney, 2020] provides a conceptual framework advocating standardized note-level encoding for unifying analysis, performance, and listener data. Given their relevance, the later chapters of this thesis examine *Attend to Chords*, *Not All Roads Lead to Rome*, and *Melody Transcription via Generative Pre-Training* as key benchmarks.

A central question arises: Are there existing systems that achieve *automatic Roman numeral analysis* without relying on *manual expert-annotated data* as pre-training for machine learning? Figure 18 shows that most *Automatic Chord Recognition* research focuses on generating basic *chord labels*, with little attention to deeper *functional harmony*. Only one study addresses advanced tasks such as *Automatic Roman Numeral Analysis*: [Wei et al., 2024], a *probing study* and *system review* introducing the *SynTheory dataset* to evaluate how generative models encode core theoretical concepts. To the best of my knowledge, and according to the present dataset, no existing work achieves *fully automatic Roman numeral analysis* without the use of manually annotated expert data.

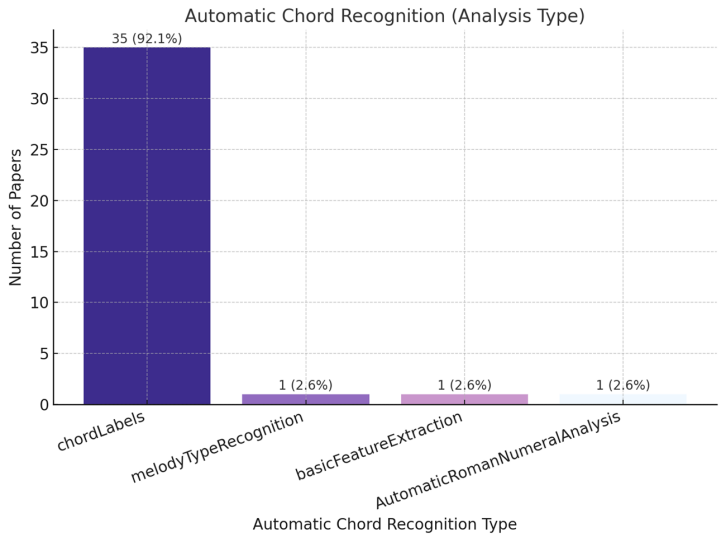


Figure 18: Distribution of Automatic Chord Recognition Type for "chord recognition" and "music tokenization" Research.

3.1 Conclusion of Data Analysis Part 2

The second dataset—focusing on *chord recognition* and *music tokenization* as processes that segment music into *discrete units*—shows that existing *Roman numeral analysis systems* uniformly depend on *expert-annotated data* as their primary source of training and validation. This dependency reveals a fundamental *technological gap*: despite advances in symbolic analysis, there is still no system capable of performing *fully automatic Roman numeral analysis* without relying on manually created expert annotations, leaving current approaches disconnected from the possibility of *scalable, multimodal, real-time research environments*.

4 Conclusion of Full Data Analysis

Between *2020 and 2025*, *music theory journals* indexed in *JSTOR* contributed minimally to *music–memory research*. As a result, the role of *structural music analysis* within *health sciences* remains limited, and even within music scholarship its applied scope is narrow. This pattern appears linked to the absence of *integrated software tools* capable of synchronizing *musical*, *behavioral*, and *electrophysiological* parameters in real time. Existing systems depend heavily on *expert-annotated data* and do not support *synchronized mul-*

timodal processing. Accordingly, this thesis argues that a fuller understanding of how *memory functions in relation to music* requires an *integrated technological framework* capable of unifying these diverse dimensions.

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