Towards Automated Musical Anamnesis for Music-based Intervention in Dementia Patients

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Abstract—**Dementia is a neurodegenerative disease affecting millions worldwide, leading to cognitive decline and difficulties in daily activities. Music-based interventions offer a promising, cost-effective, non-pharmacological approach to improving quality of life for people with dementia. However, understanding both preferred and familiar music, as well as individual music affinity, is crucial to avoid overstimulation and ensure meaningful engagement. Developing a protocol for musical anamnesis, which gathers a patient's musical history and hearing health, demands significant manual effort and expertise, limiting its scalability. An automated approach could enhance the sustainability of music-based therapy by reducing therapist time while maintaining relevance and preference evaluation. Here, we introduce Automated Musical Anamnesis (AMA), a personalized, scalable intervention combining interdisciplinary methods to support people with dementia.**

Index Terms—**Dementia, P4 Medicine, Music Therapy, Digital Therapeutics, Music information retrieval**

I. Introduction

Dementia is a neurodegenerative condition that affects millions worldwide, leading to memory loss, cognitive decline, and emotional dysregulation, which significantly reduce well-being and quality of life while increasing family caregiver distress [1]. Due to the limited efficacy and potential side effects of medications, non-pharmacological, effective, scalable, and feasible interventions are now a priority. Music-based interventions have emerged as a promising, cost-effective, non-pharmacological approach for dementia patients by tapping into preserved musical memories [2], [3]. These interventions encompass various approaches, including music therapy, where licensed music therapists design programs involving active participation (e.g., instrumental play, singing) or receptive engagement (e.g., listening). Another prevalent practice involves the independent use of pre-recorded music (music listening intervention) due to its accessibility and cost-effectiveness. Music listening interventions are not only highly accepted but also easily implemented. However, studies suggest that such interventions must meet at least two prerequisites for optimal application. First, they must engage individual autobiographical musical memories, which requires knowledge of both preferred and familiar music that can elicit such memories. Second, and perhaps more importantly, an individual's affinity for music listening must be assessed to ensure that under- or overexposure to music stimulation is avoided, thereby guaranteeing high-quality listening experiences. Additionally, with age-related hearing decline and the prevalence of conditions such as tinnitus, hyperacusis, or hearing loss—along with the potential use of hearing aids—extra care must be taken to tailor music programs to the personal needs of each patient.

Developing a successful protocol for musical anamnesis, which involves gathering a patient's musical history and hearing health, demands substantial manual effort and expertise, making it challenging to ensure scalability. Traditional anamnesis methods rely on direct interviews or questionnaires [4], [5]. Consequently, there is considerable potential for improvement in this area, leveraging both therapeutic expertise and advancements in digital technology. Automating the process of musical anamnesis can facilitate the collection and analysis of vast amounts of data, incorporating personal preferences, past musical experiences, and associated memories. This can lead to a more precise and faster understanding of an individual's musical preferences, enabling tailored therapeutic interventions. Furthermore, automating the anamnesis process can enhance personalization, adapting music-based therapy to the specific needs and preferences of each dementia patient while improving accuracy by minimizing human error and bias.

Automated systems can analyze extensive musical databases and generate personalized playlists or musical interventions aligned with an individual's background and emotional connections to music. This level of personalization has the potential to strengthen therapeutic effects and increase patient engagement while improving accessibility to music-based interventions for individuals with dementia, their family caregivers, and healthcare professionals.

This paper outlines the potential of Automated Musical Anamnesis (AMA) and demonstrates how AMA can contribute to the effectiveness and sustainability of music-based adjuvant therapies for dementia. Beyond establishing this position, the paper aims to advance the field by presenting the

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state of the art in music-based interventions while proposing a novel combination of methods and tool support, detailed in subsequent sections. Within this scope, the paper contributes to the paradigm of P4 medicine (predict, prevent, personalize, and participate) by emphasizing a personalized approach in flexible environments and a data-driven foundation, potentially enabling early detection and mitigation of symptoms in the long run. The emergence of P4 medicine, which relies on advanced sensors and low-cost digital instruments to build a new healthcare ecosystem, presents a significant opportunity with vast market potential for the European electronic components and systems industry. This includes over 25,000 SME MedTech companies across Europe and forms part of the strategic research agenda of the European ECS Industry Associations [6].

Taken together, this convergence of various fields and technological approaches—coined as a new digital reality—highlights a compelling case for infocommunications [7]. The paper is structured as follows: Section II and Section III review the state of the art in musical interventions for dementia and musical anamnesis, respectively. Section IV discusses relevant psychophysiological parameters and the sensors used to measure them. Section V presents the proposed computational modeling approach. Section VI explores the tool support from a holistic user perspective. Finally, Section VII highlights the societal relevance of the solution.

II. Current Status of Musical Intervention for Dementia

Dementia encompasses various degenerative and chronically progressive brain disorders that result in memory impairments as well as behavioral and psychological disturbances, often accompanied by high comorbidity with conditions such as depression and agitation.

Previous research suggests that music-based interventions are associated with positive outcomes at both psychological and physical levels. For instance, these interventions can elicit positive emotions [8], [9], uplift mood [10], and induce both arousing and relaxing experiences [11]–[13]. Furthermore, they have been shown to alleviate stress and anxiety and are linked to reduced cortisol levels [14]–[16]. These findings have inspired the development of practical treatment programs for adjuvant therapy targeting a broader spectrum of psychosomatic conditions and neurodegenerative illnesses [17].

The field of neurocognition provides valuable insights into musical processing and its emotional effects, which often involve activation changes in the brain's core emotion-processing structures. These findings form a crucial basis for understanding cerebral music processing and its potential clinical applications, particularly for patients with neurodegenerative disorders [17]–[19]. Although no research has specifically addressed dementia patients' assessment of digital media performance quality, relevant insights emerge from a community project involving adolescents undergoing psychiatric treatment: In this project, Mozart's works were arranged innovatively with multimedia support from a collective of artists. The intervention demonstrated individual benefits of the arts for these adolescents, including reduced psychopathological symptoms, improved self-esteem, and better emotional and behavioral regulation, including media consumption habits [20].*

Regarding dementia, music-based interventions show beneficial outcomes across various domains (see Fig. 1 for a summarizing overview). Listening to individualized, personally relevant music is particularly promising for dementia patients, as it can elicit emotional responses and tap into autobiographical memories tied to life experiences [2], [21], [22]. Studies indicate that familiar receptive music, when combined with cognitive training or physical exercise, improves overall cognitive performance compared to standard treatments. Notable improvements have been observed in attention, executive functions, orientation, verbal memory, and episodic memory. Additionally, these interventions have shown positive effects on mood, reducing symptoms of agitation, anxiety, and depression [2], [23].

However, the type of dementia may influence therapeutic responses. For example, patients with frontotemporal degenerative dementia often struggle more with emotional associations in music than those with Alzheimer's disease. This suggests that the effectiveness of interventions may vary based on the specific type of dementia. It is hypothesized that cognitive and emotional gains from music-based interventions may stem from either music-induced dopamine release and activation of the brain's reward system or stimulation of the parasympathetic nervous system [2]. Nevertheless, the causal relationship between music-induced mood improvements and underlying neurological changes remains unclear.

Imaging studies provide insights into the neurophysiological mechanisms behind musical interventions in dementia [17]. For example, research has shown that familiar music activates the medial prefrontal cortex in healthy individuals, and this brain region degenerates more slowly in Alzheimer's disease. This slower degeneration may explain why patients with Alzheimer's can recognize familiar songs and retrieve personally significant episodic memories even in the later stages of the disease [21], [24]–[26]. Additionally, King et al. [27] using functional magnetic resonance imaging (fMRI), demonstrated that listening to preferred music excerpts activates the supplementary motor area, a region associated with memory for familiar music and less affected in the early stages of Alzheimer's. They also noted increased activity in the cerebral cortex and cerebellum, which are associated with sensory and attention-related functions.

In summary, existing evidence supports receptive music as a positive factor in the treatment of dementia. However, the development of a standardized protocol for musical anamnesis

*"How to Find Myself Through Mozart": A project by Katarzyna Grebosz-Haring and Belinda Plattner in cooperation with the inter-university institution "Wissenschaft & Kunst" of the Paris Lodron University Salzburg and the University Mozarteum Salzburg, as well as the University Clinic for Child and Adolescent Psychiatry of the Paracelsus Medical Private University and the art collective "gold extra"

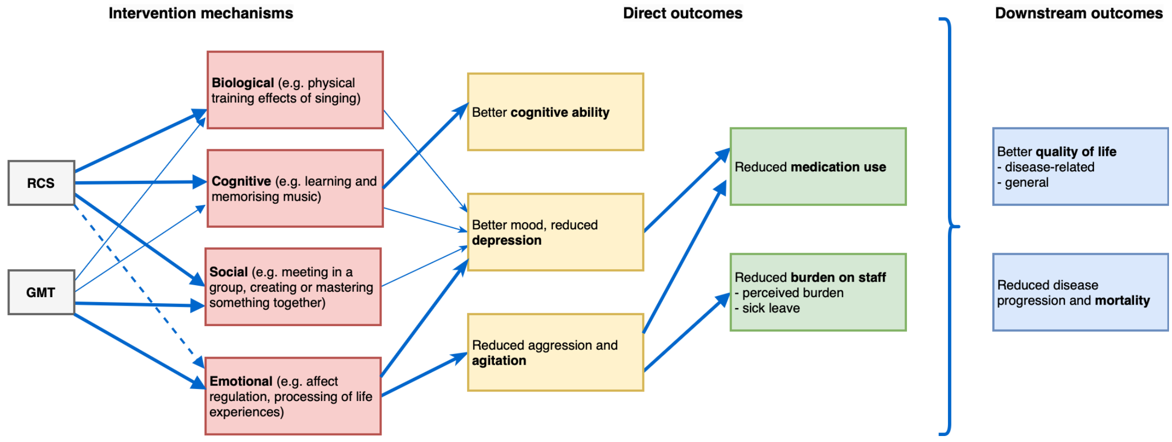

Fig. 1: Mechanisms and processes of music interventions in dementia patients. RCS: Recreational choir singing, GMT: Group music therapy

remains essential to ensure the effectiveness and scalability of these interventions.

III. Anamnesis as a process: State of the art

Anamnesis in music-based interventions aims to gather information about a patient's individual music preferences, performing history, and habits. By understanding these preferences, an appropriate selection of music and environmental factors can be prepared for subsequent music listening sessions. Typically, anamnesis is conducted through interviews and questionnaires, either via telephone or face-to-face, to identify personally relevant music for each individual. This information may be collected from family members, nursing staff, or directly from participants, provided they can articulate their preferences. Additionally, short clips of musical selections—representing genres, artists, or songs suggested in the questionnaire—may be played to the individuals. Patients are then observed for behavioral indicators such as straightening of posture, increased alertness, engagement, smiling, or moving to the rhythm of the music [28]–[30]. Relevant information includes favorite songs and artists, preferred musical genres and styles, and favored musical epochs. For patients with dementia, the primary focus is on music activation programs rather than the conventional quality of musical performance. This approach often requires extensive effort and may necessitate multiple sessions. When patients are unable to express their preferences or emotional associations verbally, trained therapists must rely on non-verbal behavior and body signals to draw conclusions. It is evident that achieving success in this area demands substantial individualized counseling time. Depending on the communicative abilities of the patient, information from proxies such as relatives or caregivers should also be considered in constructing appropriate playlists. In cases where such information is unavailable, research on autobiographical musical memory can help identify music that the patient might recognize or respond to. The advent of music streaming services has further facilitated this process, enabling immediate access to and selection of music without logistical challenges.

IV. Making use of methods: Psycho-Physiology and Sensorics

As outlined above, there is extensive evidence supporting the use of music-based interventions as adjuvant therapy. The integration of digital information technology introduces the potential for scaling these interventions, enabling broader accessibility to larger target groups in less time. Consequently, the upcoming sections present a tool support framework for AMA, detailing methods and technologies from various domains. This approach leverages cognitive abilities and digital tools to augment or substitute lost capabilities. It integrates technological and psychological expertise, along with specific requirements, as a prerequisite for clinical trials. This entails a psycho-physiological approach to measure cognitive and emotional states, translating these into parameters used to describe retrievable features of music. The methods it builds on and components required will be described in the following. The automated interpretation of cognitive capabilities requires the sensor-based assessment of associated somatic and behavioral expressions, comprising psycho-physiological and behavioral indicators: Psycho-physiological indicators, such as heart rate variability (HRV), skin conductance, and blood pressure, etc., correlate with attentional mechanisms and emotions, providing insights into arousal and valence [31], [32]. These measures exploit the body's physical reactions during or in response to cognitive activities, offering continuous data for noninvasive and noninterruptive analysis of user-stimulus interactions. However, certain psycho-physiological measures face limitations, such as high obtrusiveness (e.g., muscular tension [33], blood sugar [34]), insufficient temporal resolution (e.g., galvanic skin response [35], [36]), or poor transferability between individuals (e.g., ECG, HRV [37]). Among these, pupil dilation emerges as the most promising indicator of cognitive states [38]–[40]. Behavioral expressions of cognitive capabilities involve observable activities related to (i) information perception, such as visual attention, gaze behavior (e.g., saccadic eye movements, fixations [41], [42], head movements [42], [43]), and (ii) descriptive qualities of task and movement execution, such as steadiness and coordination of hand movements [44], [45]. The envisioned digitization of AMA focuses on analyzing and interpreting observable changes in overt behavior during music listening. Overt behavior includes body movements or posture changes observable by others, which may indicate relaxation versus tension, positive versus negative emotion, or engagement with the music (e.g., rhythmic tapping of hands, feet, or fingers). Metrics like gaze behavior and cognitive load can further assess attention and cognitive activation during music perception [28], [46]–[48].

To achieve this, relevant behaviors can be measured using various sensors, including optical sensors (e.g., cameras with skeleton tracking), body-worn sensors (e.g., accelerometers for activity recognition), and remote or head-worn eye trackers. The trade-off between sensor proximity and invasiveness influences patient acceptance and compliance. Body-worn sensors offer high data quality and immersive somatic experiences but may face low acceptance due to their invasive application and complexity, limiting scalability. Conversely, remote sensing approaches, such as camera-based systems and remote eye trackers, offer better scalability and less obtrusiveness but at the cost of reduced data quality.

A low-level remote sensing setup, such as remote eye tracking or movement detection, can serve as a starting point. Mixed or virtual reality (XR) technologies offer a promising avenue by unifying applications and digital environments [49], [50]. A harmonized XR application—such as a headset with integrated eye tracking, visual input, and interaction devices—provides an immersive environment that enhances user experience while minimizing tedious setups. Built-in sensors within XR devices are pre-calibrated, reducing the need for aligning disparate systems. Virtual reality (VR) in particular allows to aim for a broader range of positive effects when implemented effectively [51]–[54]. Successful use cases have proven the applicability of VR in medical settings [55] as well as in education [56], [57], and professional settings [58]. Thus, a target-oriented development approach, prioritizing acceptance and compliance, is essential for obtaining valid and reliable results. The use of XR headsets offers significant advantages for initial data collection due to their advanced sensor capabilities, such as integrated eye tracking and immersive engagement. However, their size and discomfort during prolonged use present challenges for patient acceptance. To address this, we propose utilizing XR headsets exclusively in the initial stage to establish a reliable baseline of cognitive and physiological responses to musical stimuli. Following the baseline assessment (and based on the patient's preferences), the process may transition to less intrusive technologies, such as remote sensors or wearable devices, for subsequent sessions.

Based on current research and available measurements, an evaluation design for AMA development should consider the following requirements: a) Intervention type: receptive interventions b) Focus of the studies: identification of behavioral and somatic reactions to presented music c) Therapy Approach: individual listening d) Intervention setting: at nursing institutions / doctor setups e) Evaluation scale: quantification of behavioral and physiological reaction to music f) Experiment design: 3 stage process for iterative refinement of music preference model.

V. Novel Combination: Computational Modeling of Musical Preference

Understanding the factors that influence individual music preferences has been widely studied over the past decade, identifying variables such as age [59], [60], gender [61], [62], cognitive style [12], and personality [60], [63]. Recent approaches to modeling user music preferences have evolved from correlating personality traits with genres or styles to leveraging finer-grained content-level features derived from the audio itself [64]. AMA builds on these advancements by employing convolutional neural networks (CNNs) to extract high-level features from intermediate network layers [65]. AI-driven models will be utilized to interpret and quantify behavioral changes on a numerical scale from 0 to 100. This process involves the multi-dimensional mapping of behavioral descriptions onto a one-dimensional score. To achieve this, AMA integrates methods from behavioral and physiological interpretation of human attention, creating supervised machine learning models for classification tasks based on multi-modal input vectors. The interpretation of reactions to music samples will be combined with music similarity models from the literature to iteratively refine sample selection for study execution. This iterative process leverages network analysis of graph representations to identify which music samples provide the most significant insights into an individual's music preference model, thereby continuously improving the computational representation of musical taste. Beyond model architecture, the approach offers flexibility for integrating elements of interaction and more complex intervention designs. For instance, the acceptance of music supporting a particular mood may vary based on an individual's current state. In a calm state, an individual may prefer calm music to maintain that state, or they may seek more arousing and activating music. The proposed approach relies on robust cognitive measures, such as attention and overt reactions, while acknowledging that more complex interrelationships and interactions with music should be explored in future iterations. These advancements extend beyond the scope of traditional anamnesis and will require further refinement.

Fig. 2 shows a design of a tool support system built by the authors to prepare such an interacting environment. It contains an XR device enabling the users to interact in a game-like setting in order to trigger emotion- and/or cognition-based reactions that can be used to gain insights into the user's emotional and cognitive states while performing a task and listening to music. Psycho-physiological measures such as built-in eyetracking as well as heart rate measurement are

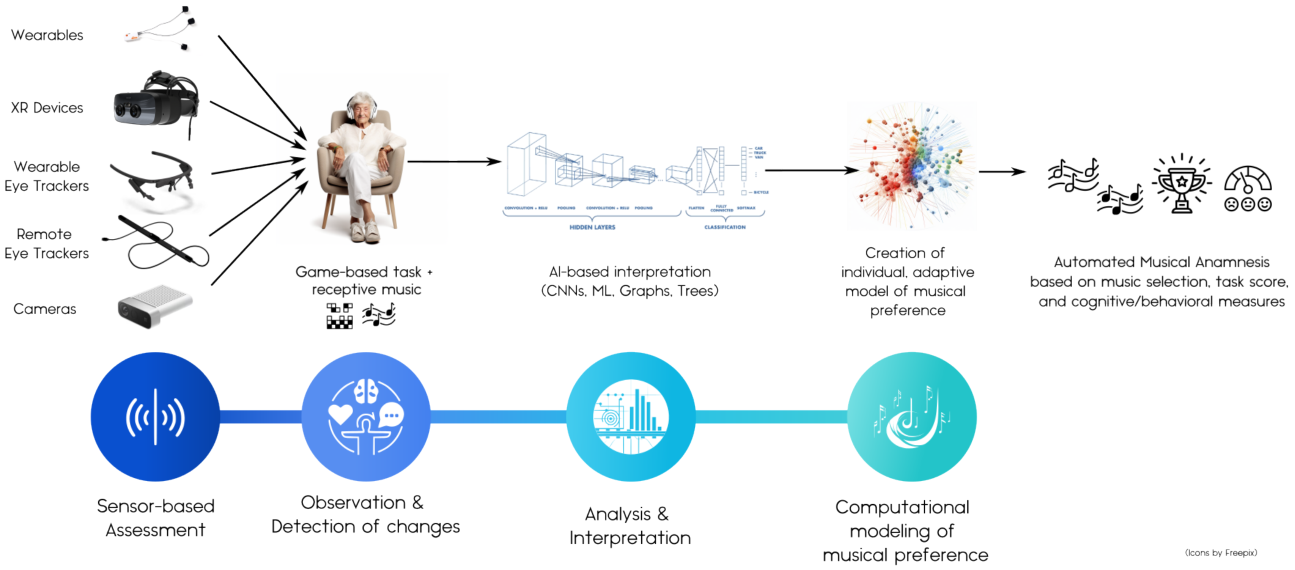

Fig. 2: Conceptual design of a tool support solution developed to conduct pilot studies for model development. A prototype was created around a reaction game with increasing difficulty built with Unity engine, a Varjo XR3 headset with eyetracking capabilites, and a self-developed protocol for structured data collection and preprocessing.

taken into account. The tool support is able to play different kinds of music to the user and analyze acquired data separately. Results will be processed into the music recommender being under development. As such, the demonstrator will be used to conduct experimental pilot studies preceding clinical studies and thereby enable the researchers to create the model described above. Further details of the setup with regard to the user-centered approach applied are described in the following section.

VI. Holistic Tool support: Integrating User-Centered Design, Methodologies, and Ethical Considerations

In a broader context, the overarching goal of an AMA system is to become a widely adopted tool in care settings. Achieving this objective necessitates the application of various methodologies and best practices. A user-centered design (UCD) approach is particularly suitable, as it involves a structured process that incorporates input from target group individuals throughout all phases of system development, including defining the context of use, establishing requirements, designing solutions, and conducting evaluations. Best practices emphasize the inclusion of all relevant stakeholders [66], [67]. Depending on the deployment environment, different stakeholder groups must be considered. While patients with dementia and music therapists are the primary users, informal caregivers (e.g., family members) and professional caregivers must also play integral roles. In nursing home settings, additional representation from staff, such as care managers and facility management (covering IT infrastructure, care documentation, and billing), should be included in the UCD process. Complementing the UCD approach with methods specifically designed for individuals with dementia is crucial to ensuring user acceptance, addressing ethical considerations, and creating solutions for patients across all stages of the condition. Tailored methods are particularly necessary for individuals with advanced dementia. The importance of the care dyad—comprising the patient with dementia and their caregiver—is emphasized in individualized care settings [68], [69]. Principles of "compassionate design" for cognitively impaired individuals, as proposed by [70], can also be applied to an AMA system. These principles advocate for designs that stimulate the senses, are highly personalized, and foster connections between people.

Methods for analyzing the acceptance of technological solutions are well-established and applicable to the development of an AMA system. The Technology Acceptance Model (TAM), which focuses on perceived usefulness and ease of use [71], and the Unified Theory of Acceptance and Use of Technology (UTAUT), which considers performance expectancy, effort expectancy, social influence, and facilitating conditions [72], are particularly relevant. While alternative technology acceptance models exist, TAM and UTAUT are widely used in healthcare [73] and are well-suited for optimizing system development. While newly developed solutions for people with dementia have the potential to enhance quality of life, it is imperative to ensure they do not compromise privacy, freedom, or human rights [74]. Consequently, the development of an AMA system will incorporate the ethical adoption model proposed by [75], which is based on five pillars: inclusive participatory design, emotional alignment, adoption modeling, ethical standards assessment, and education and training. The publication offers 18 recommendations derived from this model.

P4 medicine (predict, prevent, personalize, and participate) provides an overarching framework that encompasses all relevant objectives for developing holistic solutions in digital health and therapeutics. By emphasizing prevention and home care, P4 medicine aligns with the needs of patients suffering from chronic conditions while supporting aging well and value-based healthcare. These principles, as outlined in the Strategic Research and Innovation Agenda by the experts of the European Electronic Components and System (ECS) community [6], form a robust foundation for all user-centered and ethical considerations in the development of the AMA system.

VII. Conclusion and Final Remarks

Dementia presents a fundamental challenge to society as a whole and to each affected individual. Musical treatment approaches are among the few interventions capable of successfully activating cognitive, behavioral, and emotional resources in dementia patients, even in late stages, thereby enhancing well-being and quality of life. Significant progress has been made in understanding both the neurodegenerative effects of dementia and the potential of mitigating therapies.

However, music-based interventions face scalability challenges due to the extensive manual effort required for musical anamnesis. From a societal perspective, the urgency to develop scalable therapeutic approaches is heightened by the expected global increase in dementia cases. The development of automated processes to facilitate and objectify musical anamnesis holds the potential to deliver substantial societal impact by providing effective treatments to a broader patient population.

This paper has presented the state-of-the-art research and processes in music therapy, with a particular focus on musical anamnesis. It has explored how dementia affects cognitive and emotional capabilities, the existing interventions, and the potential benefits of these approaches. By introducing a range of methods and technological solutions, the paper outlines all necessary components for building an automated musical anamnesis tool support system. Developing an AMA solution addresses a highly interdisciplinary challenge, requiring the integration and combination of diverse methodologies. In this context, a content-driven approach necessitates a deep understanding of music and its associated contexts, while also addressing issues of inclusion, care, and sustainability. The availability of cultural content in a free and structured manner is a crucial factor, emphasizing the importance of carefully curated digitized artifacts enriched with metadata, narrativity, and interconnectedness. These elements enable the meaningful use of repositories and foster the use of both digitized and digital-born cultural heritage. For this endeavor to succeed, culture must be positioned at the core of all development steps and processes, ensuring that technological advancements go beyond functioning merely as tools for distribution or commercialization. We therefore aim at a renewed understanding of culture tech to ensure an intertwinedness of culture and technology that transcends the concept of a mere toolbox to help distribute or market content. That also includes a broader and more informed understanding of cultural heritage that is not only material for the worst-case stress test of technological developments, but rather at the core of all described endeavours [76].

Music intervention is an efficient, cost-effective, and easily applicable rehabilitation strategy for treating dementia. The proposed approach seeks to automate the labor-intensive process of musical anamnesis and content selection, enabling scalable applications and amplifying the impact of musical interventions in dementia care. It will build upon cognitive, behavioral and physiological indicators to identify interaction with presented music to automatically build models of musical preference of subjects. This innovation addresses the primary limitation of musical intervention in dementia—human effort—by providing a scalable solution that broadens accessibility and effectiveness.

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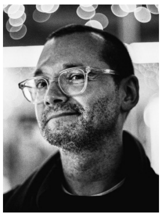

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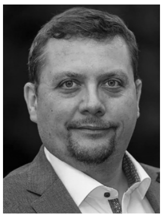

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