

An introduction to the psychoneuroimmunology of music:

history, future collaboration and a research agenda

Psy·cho·neu·ro·im·mu·no·lo·gy /, saɪkə(ʊ)ˌnɪʊəɹəʊˌɪmjʊˈnɒlədʒi/ *n.* a branch of medicine that deals with the influence of emotional states (as stress) and nervous system activities on immune function especially in relation to the onset and progression of disease

Although a modern scientific discipline, the premise of psychoneuroimmunology rests on an ancient belief that there is an interaction between mind and body; between psychological processes and health. This belief can be traced in Antiquarian records from cultures around the world: from records from India of 4,000 BC linking resistance to disease to personality types; to theories from Pergamon of 100AD hypothesising that low emotions made women more prone to cancer (Solomon, 2002).

In the intervening centuries, many branches of mind-body medicine have continued to follow the ideas presented in these early records, particularly in Eastern religions and systems of medicine. However, within many cultures of the western hemisphere, the significant medical advances of the early seventeenth-century, particularly across Europe, led to the downgrading of theories of mind-body interactions in favour of scientific 'evidence'. This was propagated by inventions such as the microscope which led to a more detailed and mechanistic view of the body (French & Wear, 2008). It was not until the mid-twentieth century that Western medicine made a marked return from a dualist view to a more encompassing holistic outlook. Solomon has described this phenomenon as a 'coming full circle' (Solomon, 1987, p.37). But this statement misses the nuance: indeed, the emphasis placed on high quality, rigorous trials and consolidated standards of reporting evidence (eg The CONSORT Group, 2010) suggests that the reliance on evidence persists in underpinning modern medicine. Furthermore, there is still a need for further development of medical practice before a true holistic approach can be realised. However, what has advanced is that the mind-body connection is no longer an unverifiable belief but is a tangible string of nerve, cell, muscle and chemical interactions, the implications of which are still being uncovered. It is this string of interactions between psychological processes, the brain and the immune system that in 1975 psychologist Robert Ader and immunologist Nicholas Cohen gave the title 'psychoneuroimmunology' (Ader & Cohen, 1975).

Psychoneuroimmunology, in its current form following the last forty years of discovery, draws together over a dozen scientific disciplines including psychology, neuroscience, immunology, biology, endocrinology, psychiatry, rheumatology, behavioural medicine, pharmacology, infectious diseases, genetics, molecular biology and physiology, amongst others, in order to provide a lens with which to view medicine. This lens allows the consideration of how changes in external environments affect the health

of individuals: how psychological processes can translate through the brain to impact on immune response, and how the immune system can, in turn, feed back to the brain and alter thoughts and feelings. This is a pertinent lens to apply to the study of music for three key reasons:

1. Music and health

Records of music being used to support health, whether apparently healing conditions from plague to wounds to poisoning, exist from across the ancient world (Fancourt, 2013). But more rigorous scientific research into the broader topic of music and health has only been brought to the fore over the last two decades. Partly, this has been in response to policy decisions from the World Health Organisation (WHO) as well as national governments such as the UK, which have created spaces for the arts (Royal Society for Public Health, 2013). But it has also been fuelled by the interest of arts organisations, by the groundbreaking work of certain universities and research centres around the world,¹ and by several pioneering research projects (e.g. Staricoff et al., 2002, as well as more recent publications such as *Music, Health and Wellbeing*; R. A. R. MacDonald & Kreutz, 2012). As a branch of biomedical sciences, immunology looks at the underpinning of a person's health, so considering its interaction with music would allow the examination of this question in greater depth. This could be relevant for a range of music practices, from music-medicine, where it could guide the integration of both live and recorded music in treatment settings; to music therapy, where it could support the development of areas such as bio-guided music therapy; to live concerts, where it could contribute to a greater understanding of the value of listening to performances on health and wellbeing. As a subset of this, articulating these possible benefits could encourage the financial investment in music and musicians for a range of settings, both healthcare and otherwise.

2. Music psychology

Psychological processes such as stress, anxiety, depression, pain and pleasure are underpinned by biological actions. Biological psychology can demonstrate not just what people perceive to be experiencing but also what their brains and bodies are physically experiencing. Considering biological actions relevant to the immune system places this within the context of a person's wider health and wellbeing. Applying this approach to music could enrich understanding of the psychological effects of music and allow the exploration of pertinent questions such as whether participants' perceptions of their own responses to music are always in line with their biological response, or whether participants can be psychologically unaware of a physiological response to music that they might be experiencing.

¹ Including the Louis Armstrong Centre for Music and Medicine, established 1994 as the Louis Armstrong Department of Music Therapy at the Beth Israel Medical Centre, New York; and the Centre for Performance Science, Royal College of Music, London established 2000; and the establishment of the International Association for Music and Medicine in 2009.

3. Evolutionary musicology

In attempting to refute the view that music does not have an evolutionary role and is instead 'auditory cheesecake' (Pinker, 1999), music psychologists and ethnomusicologists have proposed theories on music's role in evolution, including its function in social cohesion and intra-group bonding, attraction of mates, and mother-infant bonding interactions (Buss, 2005). However, another possible avenue is that music has an evolutionary role to play in stress reduction and immune optimisation, particularly if music is found to influence components of the ancient innate immune system as well as the more recently developed adaptive immune system.

Consequently, exploring how the effect of music on psychological function and brain activity extends to the immune system – the psychoneuroimmunology of music – promises to be a valuable research avenue. A systematic review on this topic by Fancourt, Ockelford, & Belai (2014) demonstrated an intriguing body of evidence: sixty-three research studies involving 8,000 participants from twenty-two countries, many of whom now host specific music-medicine research institutes. Studies involved measurements of immune and endocrine response including blood and saliva samples, alongside other markers such as blood pressure and EEGs, and in conjunction with psychological assessment. From these, alterations have been found in thirty-seven biomarkers including hormones (signalling molecules produced by glands that regulate physiology and behaviour), antibodies (also known as immunoglobulins; large proteins produced by white blood cells that target and neutralise bacteria and viruses), cytokines (small proteins that are released by cells and affect the behaviour of other cells), lymphocytes (types of white blood cell, commonly split into Natural Killer cells, T cells and B cells) and neurotransmitters (chemicals released by neurons in the brain to transmit signals). Music has been tested in a variety of modes, from recorded tapes to live concerts, music therapy, participatory workshops, instrumental lessons and choirs.

Although these data suggest promising links between music and the immune system, the paper also outlined a number of important questions that still remain to be answered, including:

- How do the aural, physical, social and personal factors involved in music combine to produce biological responses?
- Which psychological, neurological and immunological pathways are being activated to cause these responses?
- What effects does the alteration of one biomarker as a result of music have on other hormones and cells of the immune system?

Intriguingly, in the process of researching for the systematic review, the authors noticed a series of patterns amongst research studies looking at the psychoneuroimmunology of music that could be responsible for why these questions keep recurring. Essentially, there is a key challenge being faced repeatedly; something there was not space to discuss within the systematic

review. This paper aims to outline this challenge, propose a practical solution to enable the development of this promising avenue of research and present a research agenda for future studies within this area.

A disciplinary rift

In overviewing the sixty-three studies, one key linking feature became apparent: many studies into the psychoneuroimmunology of music display a lack of interrogation of the psychological processes underpinning music performance, perception and cognition. Namely, the vast majority of the work in this area has historically not been undertaken in the field of music psychology. Consequently, the insight into 'music' has been minimal. In fact, in the majority of the studies undertaken, music has been treated as a single conceptual entity with little interrogation into the kinds of physical, social, cultural and personal effects it has had on participants.

As an example, out of 63 studies, we found that only one incorporated a test that examined participants' subjective responses to the music, where participants were simply asked to rate whether the music was pleasant or unpleasant (Koelsch, Fuernetz, Sack, Bauer, Hohenadel, Wiegel, Kaisers, Heinke, 2011). This is significantly behind the sophistication of understanding of emotional reactions to music from the field of music psychology, which recently formed an entire thirty-three chapter book (Juslin & Sloboda, 2011).

Similarly, we found that sixteen of the studies allowed participants to select their own music. But the psychology of this was scarcely mentioned; certainly a far cry from the work within music psychology of Lamont & Greasley (2008) who have discussed the difference in physiological responses to familiar and unfamiliar music with a view to reaching a more grounded understanding of music preference; and MacDonald, Hargreaves, & Miell (2008) who have probed how musical preference influences identities.

Furthermore, we noticed that the mode of delivery was hardly discussed; normally chosen according to the practicalities of the study. Only three studies attempted to compare mode of delivery (ie live vs recorded) as a variable in their study. Whereas from the field of music psychology, research has shown that the location a performance of music takes place in can profoundly affect the way we interact with it (Stige, 2012, defined as the musical 'arena') and bring with it a whole host of cultural associations (Small, 1998). And the role of the performer in actually producing music rather than simply listening to it has been demonstrated to be very different (DeNora, 2000; Juslin, 2008).

The crux of this problem is that the exciting advances being made into the psychology and neurology of music are not being integrated with studies examining its immunological effects. Currently, the study of music and psychoneuroimmunology is more

the use of music *within* psychoneuroimmunology studies, than an actual interaction between music psychology and psychoneuroimmunology.

There are two possible reasons for this lack of consideration of the 'musical' component in studies. First, the majority of the studies have been carried out by medicine, psychology or immunology departments. While researchers within these departments might have a keen interest or good knowledge of music, it is relatively rare that they are also experienced music psychology researchers. The result of this is that the immunological effects of music have not been properly explored within the context of music psychology and insight into how music is achieving an immunological impact is lacking. Indeed, only nine articles in POM over the last forty years have mentioned immune function, and only one of these actually reported a study (Yamamoto, Naga, & Shimizu, 2007).

Second, both music psychology and psychoneuroimmunology are relatively recent fields of research. In fact their timelines align rather closely, building from the first publication in the journal *Psychology of Music* in 1973 and the coining of the term 'psychoneuroimmunology' in 1975. Consequently, as both have sought to establish themselves over the last few decades, the focus appears to have been on interaction with more mainstream disciplines of their respective subject areas (including psychology, neuroscience and immunology on the one hand, and including psychology, education and musicology on the other) rather than with forming more distanced connections with one another.

However, the last few years have seen these previously distanced connections begun to be made. From the psychoneuroimmunology quarter, the number of studies looking at how music impacts on immune function has increased recently: 40 studies 2003–2013, compared to 22 between 1993 and 2003, and only 1 study prior to this. And from the music psychology quarter, the 1970s broadened from a predominantly historical and analytical study of music to one that explored music and psychology (Ockelford, 2008). The last two decades in particular have moved a step further to explore music, psychology and neuroscience, as demonstrated by publications such as Peretz & Zatorre (2003). This research direction is promising for moving further to the comprehensive lens of music-psychology-neuroscience-immunology.

Currently, there is a promising body of preliminary evidence in how music can affect biological health. But if meaningful advances are to be made in this field, it will be necessary to find ways to bridge this gap between music-psychology-neuroscience and immunology and find a way of combining research approaches and pooling knowledge between the disciplines.

Achieving collaboration

The definition of collaboration has been debated over the past two decades in an attempt to give it a robust theoretical base. One of the most well-known and accepted definitions was put forward by Rosenfield (1992), who proposed three types of working: multidisciplinary, interdisciplinary and transdisciplinary; a proposition further developed by Aboelela et al. (2007).

In multidisciplinary research, teams from different backgrounds work from their own area of expertise to find different answers that might between them give a better understanding of a jointly-relevant research question. At the other end of the spectrum, transdisciplinarity involves teams drawing together a shared conceptual and methodological framework to give much more comprehensive answers to a research problem (see fig. 2). In the middle of these two poles, interdisciplinarity involves teams working jointly to address common problems or research questions, but still coming from discipline-specific bases. However, the apparent simplicity of this approach is deceptive, with a recent paper on this topic concluding that 'despite the rhetoric and apparent enthusiasm for crossing disciplines [it] remains relatively difficult to initiate, fund, publish and sustain' (Larson, Landers, & Begg, 2011, p.41).

Regarding options for collaboration between music psychology and psychoneuroimmunology, multidisciplinary research is shown by Aboelela et al. (2007) to be the simplest to undertake. However, this mode of collaboration is what the majority of research in the field so far has followed, and, as already highlighted, is insufficient for tackling the crux of issues. At the other end of the spectrum, transdisciplinary work would allow for a more dedicated space for this promising research avenue and ultimately lead the formation of a new field. However, the broad compass of both music psychology and psychoneuroimmunology, involving over 20 major disciplines and subdisciplines, makes this a complex task (fig. 1). Furthermore, this area is not so much a new field as an extension of current work on the psychology of music (from one direction) and psychoneuroimmunology of complex interventions (from the other). Instead of trying to position it amongst other areas of study as a subdiscipline of another subdiscipline, psychoneuroimmunology should be explored for its potential as a research tool working across the entire network, furthering the ability to tackle more complex research questions. In order to facilitate this sort of work, a mode of collaboration is needed that will bring together the diverse fields of music psychology and psychoneuroimmunology in more than a cursory way; in a meaningful interaction, facilitating knowledge transfer and producing more comprehensive research. But this must also be a mode of collaboration that will allow researchers to remain specific to their own disciplines in acknowledgement of the depth of knowledge required for both music psychology and psychoneuroimmunology. This approach, characteristic of interdisciplinary collaboration, appears the most beneficial path forwards for research into the psychoneuroimmunology of music. Such collaboration could bring a range of benefits, including:

1. *A broader epistemological basis.* Research so far conducted into the immunological effects of music has tended to come from an empirical viewpoint. Hypotheses have been posed and tested with some examination of the causes of these

effects. However, other paradigms have not fully been brought to the fore. Research in this area is likely to need the involvement of a combination of epistemologies, including social constructivism (as researchers seek to understand both individual and collective responses to music), pragmatism (as studies seek to answer specific questions with practical applications such as in clinical or therapeutic settings), and advocacy and participation (something already happening in other arts and health research where political changes affecting healthcare systems are opening up spaces for arts interventions and increasingly involving patients and public in the design of studies), amongst others. Interdisciplinary research could lead to this fluidity of epistemological approach.

2. *More equal disciplinary balance.* It is crucial to maintain that involving immunology with the psychology and neuroscience of music is not a way of reducing music down to a series of numbers, proteins and chemicals, but rather a way of illuminating its effects and allowing us to learn more about its impact on performers and listeners. Interdisciplinary research will support the move towards an equal collaboration: music and psychology and neuroscience and immunology; not the appropriation of music or music psychology into psychoneuroimmunology. This point is not a mere question of semantics but will be facilitated by the careful design of studies that emerge from both fields and pay equal attention to the immunological effects as to the music involved in creating them.
3. *More sophisticated analyses.* Bringing together the two very different fields of music psychology and psychoneuroimmunology would not only help to fill in some of the gaps in current understanding of the impact of music on the immune system, but also could expand methodologies and broaden research approach. Hybrids and fusions often bring with them more sophisticated analyses of problems. As Katz and Martin (1997, p.15) point out, it is in the 'clash of views' and 'cross-fertilisation of ideas' found in interdisciplinary collaboration that new insights and perspectives are gained; often significantly faster than they would have been through single-discipline working.
4. *A practical application.* There is also a very practical goal to this research: its application. Knowledge of the immunological impact of music could help its integration into healthcare setting and its acceptance from more members of the scientific community. This could improve the experience for patients – something currently high on many national healthcare agendas – and actually impact on clinical outcomes (Bleich, Özaltın, & Murray, 2009). Furthermore, if strong results are found, this could support the investment of more money and resources for music in healthcare, perhaps even providing more areas of work for professional musicians. Interdisciplinary research will allow the engagement of the healthcare and arts institutions necessary to achieve strong evidence-based practice.

5. *A progressive research agenda.* The creation of research partnerships as part of this interdisciplinary collaboration will enable the examination of more in-depth research questions. While the number of avenues to pursue is unlimited, there exist a few key topics, the answers to which could have significant implications for future research and practice.

Research Agenda

This fifth point of a research agenda is particularly important as an understanding of the range of questions still to be answered needs to be appreciated so that future studies can be designed to maximise understanding and achieve the greatest impact on practice. In light of this, a proposed research agenda is outlined below. It is structured into three core themes: 'biology', looking at the molecular biomarkers that might be involved in responses to music and how these could be examined; 'psychology', exploring some of the perceptual mechanisms involved in biological responses to music as well as some of the musical parameters affecting these changes; and 'practical application', examining some of the fundamental questions relating to participants and musical activity currently hindering the ability both to generalise from research studies and develop projects based on their results.

Given the number of questions still to be answered, each key research question proposed here is categorised as 'high priority' if answers are likely to have a significant impact, or given a lower status of 'other research needs'. In addition, short rationales are provided for each question to provide some context to the question and reference other studies relevant to this area. This agenda should not be taken as a definitive list of the only questions still to be answered, as there remain an infinite number of avenues to explore, but can be used as a guide for some of the main areas still to be researched.

Theme 1: Biology

High priority:

a. Establish the range of effect that music can have on biomarkers

Rationale: Research so far has already pointed to the effects of music on biomarkers of the central nervous, endocrine and immune systems. Future research needs to ascertain how widespread within these systems the effects of music are and how great a change in response music is able to affect. For this to be achieved, research into the psychobiology of music will need to take place in close partnership with research into the medical and life sciences; in particular technological developments that allow for easier and faster testing of a growing range of biomarkers.

b. Trace the pathways involved in immune responses to music

Rationale: As well as working at a molecular level, future studies also need to look at broader movements. Studies involving multiple biomarkers are showing evidence of the up-regulation and down-regulation of specific pathways, such as pro- and anti-

inflammatory cytokines and neurological reward circuits (E.g. Kimata, 2003). Such research is dependent on multiplex testing, as smaller studies involving fewer biomarkers risk missing results. For example, a single-biomarker study by Brunges & Avigne (2003) demonstrated that recorded music could decrease levels of adrenaline (epinephrine) but had no further detail. However, a multi-biomarker study by Conrad et al. (2007) showed that in similar conditions not only was adrenaline decreased, but simultaneously growth hormone and interleukin-6 were increased and dehydroepiandrosterone (DHEA) was prevented from falling. This led Conrad et al. to be able to hypothesise a pathway for the impact of music on adrenaline; something not possible in Brunges' and Avigne's study. Research using multiple biomarkers could also help with the identification of which pathways are most dominant and which provide the strongest links between music perception and immune function.

c. Start to identify the effects of music on the biomarkers most important to specific health conditions

Rationale: Many studies so far have focused on the impacts of music on healthy populations. However, this does not enable accurate extrapolation to other patient groups. Indeed, research is demonstrating that healthy individuals exhibit greater flexibility in adapting to their external environments, so are likely to show smaller biomarker response (Gerfen, 2008). For other patient groups, it remains uncertain whether an equal or greater biological response is found following exposure to music; something that will be important to determine so that effects are accurately stated. Furthermore, for many major health conditions, there are now a range of biomarkers recognised as being of particular importance. For example, within mental health conditions such as depression, pro-inflammatory cytokines such as IFN-gamma, TNF-alpha and IL-6 have been linked closely with serotonin (5-HT) function and consequent mood changes (Dowlati et al., 2010; Dunn, Swiergiel, & Beaurepaire, 2005). And in cancer, certain biomarkers can play crucial roles at various stages of disease progression, such as vascular endothelial growth factor (VEGF) in metastasis (Roberts, Cossigny, & Quan, 2013). As well as examining general reactions to music such as stress response, future studies should focus on biomarkers particularly relevant to the study population. This will require close collaboration with clinicians and researchers within each field in order to balance the complexities of possible confounding variables, from disease states to the effects of medication.

Other research needs:

d. Compare the biological impacts from music with other interventions

Rationale: As research on the biological impact of music grows, studies should try to form direct comparisons with other treatment methods; for example, whether a ten-week course of group music making for mental health produces equal or better outcomes to ten weeks of more standard treatment, such as psychotherapy or medication. Research such as this will be crucial in enabling clinicians and commissioners to see the value of music interventions and in facilitating their adoption in clinical as well as public health settings.

Theme 2: *Psychology*

High priority:

a. Test how music is having a biological impact

Rationale: Fancourt et al. (2014) outlined a model in which four key independent variables were responsible for biological change. Each of these variables remains to be explored in more detail, with a number of key questions for each:

Aural. Although a well-researched area within music perception and music psychology, there remains little research on the specific parameters of music involved in biological response, such as compositional elements including consonance, timbre and tempo. In particular, research in this domain could inform the use of background music in public settings.

Personal. Research from psychologists such as Patrick Juslin and Daniel Västfjäll is showing how complex emotional responses to music are (Juslin & Västfjäll, 2008). At the same time, psychoneuroimmunology research is providing burgeoning evidence as to the effects of different emotions on immune response. Such research needs to be synthesised in future studies in order to provide an understanding of the impact of personal responses to music on the immune system.

Social. There have been a number of studies over the last decade exploring how social interaction affects immune response, with social factors such as support networks even having long-lasting effects on the development and progression of chronic immune diseases (Lutgendorf, Costanzo, & Siegel, 2007). Music is, evolutionarily, a social activity, and, as recent psychological studies are demonstrating, there are strong social effects of music-making (Christiansen & Kirby, 2003). There is also a growing body of literature looking at the impact of environments on biological function, showing that improved aesthetics and reduced background noise can down-regulate stress response (Suresh, 2007). So carefully controlled studies of music are needed to ascertain how much of the biological response to music is as a result of this strong variable of social interaction, and also to separate responses to music out from responses to other environmental stimuli.

Physical. Psychoneuroimmunology research is equally showing how physical activity, even in small quantities, can modulate biological response (Nieman, 2007). Studies involving active participation in music need to take into account the additional effects of the physical activity required, whether increases in oxygen consumption as a result of singing, or energy breakdown and muscular exertion from activities such as drumming.

In order to understand truly the impact of these four independent variables on biological response, all future studies are going to have to place much greater value on reporting the components of the music interventions, whether music choice, setting, social engagement of participants and physical exertion involved. It may also be necessary to clarify the use of the term 'music':

if it is used in the purest sense of components of sound (the aural variable), then it remains to be seen how much of the biological response is as a result of the 'music' itself. Research so far suggests that the other three variables (personal, social and physical engagement) may play an equally, if not more, important role. So either researchers will need to ensure that studies define 'music' in a broader way that encompasses these additional variables. Or the biological study of music will need to be reframed so that music is seen as a vehicle that enables physical activity, social interaction and emotional response to be achieved and subsequent biological activity to take place, recognising that it is less likely that participants could be induced to undertake these other three activities without the core motivation of music.

b. Identify correlations between perceived and actual change

Rationale: Future studies also need address whether self-perception of change, such as feelings of relaxation, is matched with biological change. While biomarkers are capable of changing very quickly, they can equally show 'rebound' effects, whereby results reverse after a period of minutes, hours or days. These rebound effects can sometimes be of greater significance for systemic immune change than the initial effect. It will be revealing to understand which effects lead to the greatest psychological symptoms. As a side-line, many biomarkers are being linked to specific behaviours, such as certain pro-inflammatory cytokines being linked to insomnia and loss of appetite (Dunn et al., 2005). For longer music interventions, research is needed to ascertain whether biological changes as a result of music can affect behavioural response. The impact of music on behaviour has been explored in a few studies (e.g. Perkins & Williamon, 2013), but whether this is as a result of an underlying biological response is yet to be explored.

Other research needs:

c. Compare results from saliva and blood testing with other physiological measures

Rationale: There are a growing number of technologies available to test physiological response, from simple devices such as blood pressure monitors to more complex ECG machines for heart-rate variability, a range of imaging technologies for brain imaging, and analyses of gene expression. As yet, there is very little research on how biological responses to music correlate with other physiological results. Future research could start to identify how such responses interact and possibly enable the development of comparative indices so that high levels of certain physiological measures are known to be simultaneously producing specific results from biomarkers.

d. Distinguish between biological responses to relaxing nudged stressful stimuli

Rationale: Fields such as performance science are producing a burgeoning body of evidence on the negative effects of music-induced stress (whether aural or physical) on physiological response. So far, the majority of studies in the psychoneuroimmunology of music have been testing for positive change, whether using relaxing or stimulating music. But as a

sub-focus of study, it will be revealing to understand how stressful sound, such as loud or disliked music, affects biological response, both in order to compare the differences to positive responses to music and see what is revealed, and to understand the dangers of stressful music.

Theme 3: *Practical application*

High priority:

a. Track the effects of music on biomarkers across varying timespans

Rationale: Building on information being gathered on rebound effects (outlined in psychology agenda point b), the exact time points at which samples are taken should be more accurately measured and more consciously decided on as these could be acting as co-variables in measuring biomarker levels in response to music. Future research needs to ascertain these fluctuating patterns of biomarkers across both short and longer timespans to enable us to assess with much greater accuracy complex immune responses to music. Such research will also help us understand how long the effects of music can be expected to last; whether single interventions are capable of exerting effects of longer than a few minutes after, and how many repetitions of interventions are needed to have long-lasting effects.

b. Elucidate the effects of external factors affecting music perception on biological response

Rationale: Research literature so far is demonstrating how music perception can affect neural and affective responses to music (Parbery-Clark, Anderson, & Kraus, 2013). Even on a basic level, receiving music through headphones carries with it additional effects such as blocking unfamiliar background noise in clinical settings. Research studies need to identify how biological responses to live music differ from recorded music, how active listening versus more passive consumption of background music affects biomarkers, and how variables of perception such as volume of music alter the strength of immune response. This will serve the practical purpose of informing the ways music programmes are designed in healthcare settings and improve awareness of the effects of personal listening habits.

Other research needs

c. Demographic responses to music

Research from within psychoneuroimmunology is demonstrating the impacts of demographic factors such as age, ethnicity and gender on immune response (Robinson, Mathews, & Witek-Janusek, 2002). Incorporating such data into future studies on music will enable a much more sophisticated understanding of biological effects. Understanding variations dependent on age will in turn allow a greater understanding of cultural variables, enabling us to isolate which biological responses are evident at a very young age, such as in new-borns, and thus relatively innate, and which are more dependent on cultural conditioning, and thus acquired.

Conclusion

This paper has outlined the historical foundations and current research portfolio for studies exploring the psychoneuroimmunology of music, as well as identifying a current weakness in research strategy and proposing both a theoretical mode of collaboration and a research agenda to enable the advancement of knowledge within this area. It should be stressed that this approach is not being suggested as an alternative to research in pure music psychology or other types of research into the health benefits of music or music therapy. Indeed, there is a concentration, purity and depth of insight that can be gained from concentrated single-discipline studies, and immunology will not always be relevant to research questions. Instead, it is being proposed as a way of broadening the scope and sophistication of techniques to allow the answering of more complex research questions. Part of the aim of the interdisciplinary approach outlined here is to keep boundaries fluid, allowing the engagement of new areas of science and music where such involvement can stimulate intellectual curiosity, introduce fresh ideas and help solve research problems. But at the same time, by having a more structured approach to the way we work and a clear direction, it will hopefully help in the achievement of what Aboelela et al. (2007) have called for: a move from 'a random, unsystematic occurrence to an essential, teachable research approach', turning the psychoneuroimmunology of music into a strong research avenue.

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