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The modulating effects of music listening on health-related exercise and physical activity in adults: a systematic review and narrative synthesis

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A systematic review and narrative synthesis of theories was conducted to examine the modulating effects of music listening on health-related exercise and physical activity. Searches were conducted on multiple bibliographic databases from the earliest available date until April 2013 using the key terms of music, physical activity and theory and related synonyms. Two reviewers independently screened retrieved texts using the inclusion and exclusion criteria. The quality of included texts was appraised using a checklist, and key concepts were recorded and synthesised using inductive thematic analysis. The narrative synthesis comprised 23 theoretical texts representing three contexts: therapeutic outcomes, sports and exercise performance, and auditory-motor processing. The quality appraisal demonstrated some limitations in the reporting of evidence informing theories. Analysis across all texts identified a main theme, cortical and subcortical stimulation and response, and two sub-themes, physiological arousal and subjective experience. These themes contributed to a common hypothesis that music could promote behavioural change with increased exercise adherence and participation. A meta-theory is presented, offering a framework for clinical practice and research. Music therapists might use the meta-theory to inform music listening interventions in programmes that aim to increase levels of physical activity.

Keywords: music listening; systematic review; theory; exercise; physical activity

Introduction

Music has been used throughout history and across cultures to stimulate movement and accompany exercise (Freeman, 2000). This influence of music might have an impact on three differing but related factors comprising movement, exercise and physical activity. Movement results from skeletal muscle activation,

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exercise describes planned behaviour designed to improve physical fitness and health, and physical activity is repetitive movement, often in the form of exercise, that increases daily energy expenditure (Caspersen, Powell & Christenson, 1985). The relationship between music listening and repetitive movement in the form of health-related exercise deserves further scrutiny, as this inexpensive and accessible intervention might support exercise participation, leading to improved levels of physical activity and associated health outcomes (Warburton, Nicol & Bredin, 2006; Wen et al., 2011).

Influences of music on movement are described as multifaceted, affecting cognitive, sensory motor, and psycho-emotional processes to support coordination of repeated movement patterns during exercise (Altenmüller & Schlaug, 2012). Motion-capture studies illustrate this phenomenon, explaining spontaneous relaxation and contraction of muscles in response to tension, resolution and rhythm in music as an embodied form of music cognition (Burger, Thompson, Luck, Saarikallio & Toiviainen, 2013). Other research has focused on the influence of rhythm in music, demonstrating that patterns in bodily movements influence how rhythm is perceived (Phillips-Silver & Trainor, 2007) and that tempo and beat preferences have an impact on the magnitude of response (Kornysheva, von Cramon, Jacobsen & Schubotz, 2010; MacDougall & Moore, 2005; McAuley, Jones, Holub, Johnston & Miller, 2006). Further, neuroimaging research examining music listening demonstrates stimulation of the limbic and para-limbic structures in the brain corresponding with subjective feelings of motivation and reward (Koelsch, 2010), suggesting that music listening might have a positive influence on emotions during exercise.

For the purposes of this article, music listening describes the use of music by exercise participants to support health-related exercise and physical activity in the form of repetitive movement, such as walking. While many describe dance as a form of exercise (Kreutz, 2008), there are differences between engaging with music in dance and simply listening to music during health-related exercise. Dance demonstrates an intimate relationship between human movement and music, which stimulates aesthetic and creative experiences (Quiroga Murcia & Kreutz, 2012), offering several psychophysiological and social benefits (Quiroga Murcia, Bongard & Kreutz, 2009). In comparison with music listening for health-related or recreational exercise, dance is a performance that usually requires the presence of music (Kreutz, 2008), while exercise is frequently performed without music. Therefore, there is a distinction between the integration of music with dance and the use of music listening to support health-related exercise and physical activity.

It is plausible to assume that the influences of music on exercise and physical activity may have been widely investigated by researchers with differing disciplinary and epistemological perspectives, leading to a number of theories describing various philosophical viewpoints. Therefore, we conducted a systematic review and narrative synthesis of theories (Popay et al., 2006), to gain a greater understanding about the modulating effects of music listening on health-related exercise and physical activity.

Narrative synthesis, a textual method of combining qualitative evidence in systematic reviews to explore a concept, is useful when the included literature is diverse and derived from heterogeneous research designs and various epistemological frameworks (Gough, Thomas & Oliver, 2012; Popay et al., 2006). Consistent with a systematic review, a specific question is recognised, and the method involves transparent search strategies, inclusion and exclusion criteria, data extraction procedures and quality appraisal (Popay et al., 2006). In the current article, we aimed to "configure" theories using an iterative process to synthesise different approaches and create a "meta-narrative summary" (Gough, 2013, p. 2). Specifically, this systematic review and narrative synthesis reviewed current theories or conceptual frameworks and asked how, and in what contexts, does music listening modulate health-related exercise and physical activity?

Method

Literature searches

Systematic searches of electronic databases were conducted from the earliest available date until April 2013 for (1) peer-reviewed journal articles using MEDLINE, CINAHL, EMBASE, AMED, PsychINFO, Expanded Academic ASAP, The Cochrane Library, ProQuest Central, ProQuest Health and Medical Complete, Scopus, RILM Abstracts of Music Literature, Music Index, AUSPORT, SPORTDiscus, Academic Search Complete, Health Source – Consumer Edition, Health Source – Nursing/Academic Edition, MasterFILE Premier, Psychology and Behavioural Sciences Collection, and Rehabilitation and Sports Medicine Source; (2) theses and dissertations through Australian Thesis in Trove, EThOS – Beta, Networked Digital Library of Theses and Dissertations Union Catalog, ProQuest Dissertations and Theses, Theses (Informit); and (3) textbooks using Australian Libraries electronic catalogue, Trove http://trove.nla.gov.au, and Google Book. Potentially relevant texts known to the reviewers were also included for consideration.

The search strategy included three key concepts: (1) *music* as the only term; (2) *physical activity*, OR synonyms *exercise* OR *movement* OR *motor activity* OR *sport* OR *fitness*; and (3) *theory*, OR synonyms *theoretical* OR *philosophy* OR *review* OR *conceptual* OR *meta-analysis*. Results from the three key concept searches were combined using the AND operator. Where possible, the key concepts music, physical activity, and theory were mapped to subject headings, and limiters for humans, adults and English language were applied. Results from these searches were collated into an electronic bibliographic library, and duplicates were removed (Endnote X6 Thomson Reuters).

Eligibility criteria

Theories grounded in evidence written in English describing the impact of music on exercise and physical activity, reported in books, peer-reviewed journal articles, higher degree theses and dissertations were included. Given this broad topic and the subjective nature of theories, eligibility criteria and definitions aimed to provide clear boundaries for answering the question and managing large amounts of literature.

A theory, for the purpose of this review, was defined as a supposition based on logically and comprehensively integrated principles derived from extensive high-quality research (Bruscia, 2012b). High-quality research included quantitative evidence comprising systematic reviews, randomised controlled trials and cohort studies (Akobeng, 2005), and/or generalisable qualitative evidence grounded in theory with rigorous sampling criteria and data analysis techniques (Daly et al., 2007). Results from single trials, and theories based on single case studies, programme descriptions and opinions without support from rigorous research, were excluded from this review (Daly et al., 2007).

To capture broad interpretations supporting the use of music for physical activity and exercise, no limits were placed on the gender or the condition of participants who had been included in research informing the theories. However, the review was limited to adults 18 years and older.

Theories were included if they described music listening to support exercise and physical activity outcomes. Music, for the purposes of this review, combined rhythm, melody, harmony, and timbre arranged in unified continuous sequence, capable of facilitating meaningful aesthetic experiences, engagement and response (Eagle, 1996). Further, music listening needed to be the primary intervention being examined for its influence on human physical activity and exercise, and the term “music” was included in the title and/or abstract. References describing the influence of music listening combined with another medium, such as videos or aromas were excluded, as effects could not be exclusively attributed to music. Further, owing to the intimate relationship between music and dance (Quiroga Murcia & Kreutz, 2012), we chose to exclude theories examining dance and music, as these might not clearly illustrate the modulating effects of music as a primary intervention for health-related exercise and physical activity. There were no limits on types of music production or styles, with the inclusion of any live and recorded music listening interventions.

Theories describing the influence of music listening on movement, exercise and physical activity outcomes were included. Therefore, theories needed to include evidence describing movement as muscle activation, exercise as planned structured activity designed to increase or maintain physical fitness and physical activity as repetitive movement that increased daily energy expenditure (Caspersen et al., 1985). Consequently, research examining the influence of music on concepts that did not directly involve muscle activation, physical

Table 1. Eligibility criteria.

	Inclusion	Exclusion
Participants	Adults ≥ 18 years of age	Infants and children
Music listening interventions	Primary intervention being examined. Arrangement of musical elements (rhythm, melody, harmony and timbre)	Single metrical pulse (e.g., metronome). Theories describing the music in combination with other interventions, such as dance or video
Physical activity outcomes	Influence of music listening on health-related exercise and physical activity outcomes	Outcomes not related to physical activity (e.g., relaxation, stress, anxiety, physical development, music/instrumental performance, exercise recovery, sleep)
Methodology	Theories based on evidence from multiple studies describing rigorous research	Single studies, case studies, programme descriptions and opinions
Publications	Peer-reviewed books, journals, higher degree theses and dissertations	

fitness or energy consumption, such as relaxation, stress management, sleep, physical development or education, was not included in this review (Table 1).

Study selection

Two reviewers independently applied inclusion and exclusion criteria to titles and abstracts collated in the bibliographic library. Results between the two reviewers were compared, and following mutual agreement, full texts were retrieved for further assessment using inclusion and exclusion criteria. Agreement between the two reviewers was sought to determine final inclusions for the narrative synthesis and reported with the kappa statistic (κ) and 95% confidence intervals (CI). In situations where two reviewers were unable to come to an agreement, a third reviewer joined discussions to facilitate a decision. Reference checking and citation tracking of the included references was undertaken to identify additional inclusions.

Data extraction

Data were extracted and documented using an extraction form developed to identify relevant information. Details recorded from each reference included the author's background and discipline, type of publication, a summary of the theory, descriptions of key concepts informing the theory and notes describing principal studies informing each theory (study designs, participants, sample sizes, settings, music interventions, physical activity outcomes, results). Data and information were extracted by one reviewer and checked for accuracy by a second reviewer. Any discrepancies were discussed amongst three reviewers and resolved with reference to the full text.

Risk of bias

Appraising the risk of bias in theories presented challenges. Theories represent points of view derived from various perspectives, background knowledge and epistemologies, which cannot be compared or standardised (Bruscia, 2012a). Therefore, a checklist with nine criteria was created to appraise each theory. It should be noted that these criteria were intended not to evaluate the quality of theories in general but to appraise them with respect to the current review and the research question. The first five criteria appraised coherence, clarity, comprehensiveness, relevance and usefulness (Bruscia, 2012a). A further four criteria evaluated the strength of evidence from studies informing the theory (Shea et al., 2009). Two reviewers independently examined each of the included references to assess whether criteria on the checklist were fulfilled or not. Results were then compared, and any discrepancies discussed until consensus was achieved (see Supplemental data for the quality appraisal).

Data synthesis

We anticipated that theories describing the influence of music on movement, exercise and physical activity would include evidence from quantitative and qualitative data, making inductive thematic analysis an appropriate method for synthesising, analysing and reporting the included texts (Braun & Clarke, 2006; Popay et al., 2006). Data in the form of descriptive interpretations about the influences of music on movement, exercise and physical activity were extracted from each of the included texts. These data were scrutinised in a recursive manner with reference back to the texts to ensure that main points had been identified, and summary statements were written for each text. Following this, codes were generated to represent key concepts across summary statements from all the included texts. Mind mapping was used to assemble codes, and patterns and similarities were identified as themes and sub-themes. The mind mapping process was repeated several times until the researchers were satisfied that all codes were represented, and no new themes or sub-themes were emerging. Content analysis, conducted as a secondary measure, involved counting the numbers of texts contributing to each theme and sub-theme to demonstrate strength of support across the included texts (Popay et al., 2006). A critical appraisal of texts also impacted on the strength of evidence supporting themes and final conclusions. Finally, a narrative was written clearly describing the specifics of each theme, and how each theme contributed to the broader analysis answering the research question (Braun & Clarke, 2006; Popay et al., 2006).

Results

Study selection

The search resulted in 1508 texts, with an initial library of 1165 following the removal of 343 duplicates. Two reviewers demonstrated very good agreement with exclusion of 1128 and retention of 37 references (κ = 0.80, SE = 0.06, 95% CI = 0.69, 0.91). Three further texts, identified by experts but not retrieved during electronic searches, were assessed as being eligible and added to the library (DeNora, 2000; Schneck & Berger, 2006; Thaut, 2005), resulting in 40 full texts. Review of full texts resulted in good agreement between two reviewers with 23 inclusions, 13 exclusions and 4 texts that were unclear and required input from a third reviewer to decide whether they met our inclusion criteria (κ = 0.79, SE = 0.10, 95% CI = 0.59, 0.98). Consensus between the three reviewers resulted in the exclusion of these four texts, with a final review library of 23 texts. No further texts were found during reference or citation tracking (Figure 1).

Theory characteristics

Three different contexts describing the influence of music on movement, exercise and physical activity were identified across the 23 texts: (1) therapeutic effects (n = 9); (2) exercise and sports performance (n = 11) and (3) auditory-motor processing (n = 3).

Therapeutic effects

These theories described a capacity in music to support motor movement and neuroplasticity leading to the accomplishment of clinical goals in neurorehabilitation and medical contexts. The rhythmic, temporal, harmonic, timbre, melodic and dynamic elements in music can be manipulated to encourage the relearning of functional motor patterns. Music was also implicated as a stimulus of hormonal and biochemical changes, which are associated with positive emotion, mood and effect and may impact experience during rehabilitative exercise (Altenmüller & Schlaug, 2013; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006). Within this theoretical framework, persistent exposure with music altered instinctive and planned behaviour, thereby stimulating neurological adaptation. Further, the aesthetically pleasing aspects of music listening or the reward from skill acquisition during instrumental performance may lead to improved exercise adherence and the attainment of health and rehabilitation outcomes (Altenmüller & Schlaug, 2013; Murrock & Higgins, 2009; Paul & Ramsey, 2000; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut & Abiru, 2010; Thaut, Kenyon, Schauer & McIntosh, 1999; Thaut & McIntosh, 1999) (Table 2).

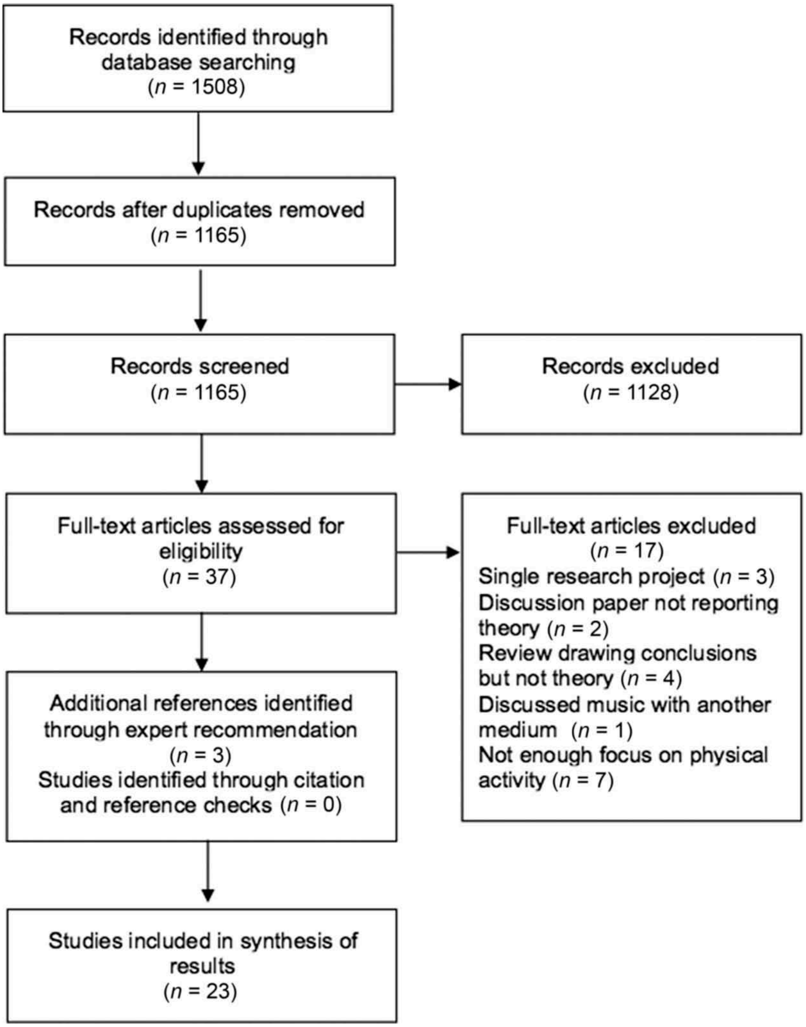

Figure 1. Search results flow chart.

Sport and exercise performance

These theories proposed that listening to strategically selected music leads to beneficial physiological and psychological responses that improve exercise performance, experience and adherence. Exercise participants appropriated music (DeNora, 2000) to regulate mood and distract from discomfort in anticipation of the expected environmental and physical demands. The affording qualities of music (DeNora, 2000), rhythm and tempo were described as the most influential

Table 2. Characteristics of therapeutic theories describing the modulating effects of music listening on exercise and physical activity.

Reference	Author discipline & publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Altenmüller and Schlaug (2013)	Review Music therapy Neurorehabilitation	Designs: experimental, observational; Participants: neurologically impaired & healthy; Settings: rehab, lab; Music: NMT (music listening and performance); PA: functional movement; Measures: neuroimaging, EEG, physiological; Findings: neuroplastic changes, improved gait and upper-limb function	Subcortical/cortical Rhythmic stimulation Neurophysiological response Diversion Behavioural response	Music stimulates neurological processes influencing brain plasticity, emotions, motor movement and behaviour
Murrock and Higgins (2009)	Review Nursing	Designs: experimental; Participants: CVA, PD, ABI, CD, COPD, obstetrics, surgery; Settings: health, lab, nat; Music: listening; PA: walking, dancing, aerobics; Measures: physiological, psychological; Findings: improved health outcomes	Alters mood Rhythmic stimulation Diversion Behavioural response	Music improves mood, movement and enjoyment during exercise and may increase levels of physical activity
Paul and Ramsey (2000)	Review Music therapy Occupational therapy	Not specifically reported but identified: Participants: ABI, PD, CVA, CD; Settings: rehab; Music: NMT (music listening and performance); PA: functional movement; Measures: Physiological, EMG; Findings: improved physical function	Rhythmic stimulation Skill acquisition Behavioural response	Music positively influences the achievement of functional goals in neurorehabilitation

(*continued*)

Table 2. (*Continued*).

Reference	Author discipline & publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Rodriguez-Fornells et al. (2012)	Review Music therapy Neurorehabilitation	Designs: experimental, observational; Participants: neurologically impaired and healthy; Settings: rehab, lab; Music: instrument playing; PA: functional movement; Measures: fMRI, TMS, psychological, cognitive, motor movement; Findings: improved physiological, cognitive and psychological outcomes	Subcortical/cortical Rhythmic stimulation Neurophysiological response Positive experience Behavioural response	Music participation activates auditory-motor connectivity leading to neuroplasticity and functional motor movement
Schneck and Berger (2006)	Book Biomedical engineer Music therapy	Designs: experimental, observational; Participants: neurologically impaired and healthy; Settings: nat, clinical, lab; Music: listening and participation/performance; PA: functional movement; Measures: neuroimaging, EEG, physiological, lesion comparisons, behavioural; Findings: physiological and psychological entrainment with music forces behavioural response	Subcortical/cortical Sensory stimulation Rhythmic entrainment Neurophysiological response Behavioural response	Music is a driving force that facilitates physiological entrainment, functional adaptation and behaviour change, making it an effective therapeutic tool
Thaut and Abiru (2010)	Review NMT	Designs: experimental; Participants: CVA, ABI, PD, HD, CP; Settings: rehab; Music: NMT (music listening and participation); PA: functional movement; Measures: motor movement; Findings: improved functional motor movement	Rhythmic entrainment Neurophysiological response	RAS facilitates entrainment and functional movement in people with neurological impairments

(*continued*)

Table 2. (*Continued*).

Reference	Author discipline & publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Thaut (2005)	Book NMT	Designs: empirical, experimental; Participants: healthy, neurologically impaired; Settings: rehab; Music: NMT (music listening and performance); PA: functional; Measures: motor movement, neuroimaging, EMG, physiological, psychological, cognitive; Findings: music supports attainment of functional rehabilitation goals	Subcortical/cortical Rhythmic stimulation Neurophysiological response Skill acquisition Emotional response Behavioural response	Rhythm and tempo influence perceptual processes, to "train the senses, the body, and the mind" (p. 37)
Thaut et al. (1999)	Review NMT	Designs: experimental; Participants: CVA, PD; Settings: rehab; Music: NMT (music listening and performance); PA: functional movement; Measures: motor movement, EMG, neuroimaging, physiological; Findings: improved sensorimotor function	Neurophysiological response Rhythmic entrainment Skill acquisition	Rhythm stimulates physiological and behavioural response in people with movement disorders
Thaut and McIntosh (1999)	Review NMT	Designs: experimental; Participants: elderly (CVA, PD); Settings: rehab; Music: NMT (RAS); PA: motor movement; Measures: motor movement, EMG; Findings: functional motor improvements	Rhythmic stimulation Neurophysiological response	Rhythmic stimuli entrain movement frequency and stability in elderly people with movement disorders

Notes: Rehab = rehabilitation; lab = laboratory; nat = natural; PA = physical activity; EEG = electroencephalogram; CVA = cerebral vascular accident; PD = Parkinson's disease; ABI = acquired brain injury; CD = cardiac disease; COPD = chronic obstructive pulmonary disease; NMT = neurologic music therapy; EMG = electromyogram; fMRI = functional magnetic resonance imaging; TMS = transcranial magnetic stimulation; HD = Huntington's disease; CP = cerebral palsy; RAS = rhythmic auditory stimulation.

features of music during exercise, with lesser impact derived from pitch-related elements (melody and harmony) or lyrics. Personal factors including age, gender, training status, personality and social and cultural factors also influence the effectiveness of music during exercise. Taking these factors into account, exercise participants described music as a source of motivation during exercise (Bishop, 2007; DeNora, 2000; Priest, 2003; Harmon & Kravitz, 2007; Karageorghis, 2008; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997, 2009; Karageorghis, Terry, Lane, Bishop & Priest, 2012; Koc & Curtseit, 2009) (Table 3).

Auditory-motor processing

These theories described music as a stimulus for complex cortical and subcortical neurological processes influencing motor movement, emotional response, and neural plasticity. Principal brain structures demonstrating involvement in auditory-motor processes include the cerebellum, basal ganglia and motor cortex (pre-motor area and supplementary motor area). Repetitions in movement appear to correlate with phases between two consecutive music beats, involving a feedback/feedforward loop, which facilitates error correction and the execution of precise and accurate movements when rhythmic patterns in music are heard (Levitin & Tirovolas, 2009; Todd, Lee & O'Boyle, 2002; Zatorre, Chen & Penhune, 2007) (Table 4).

Theory appraisal

Appraisal of theories using the checklist resulted in a very good level of agreement between two reviewers ($\kappa = 0.82$, SE = 0.05, 95% CI = 0.73, 0.91). Most of the included texts were appraised as having coherence, clarity, comprehensiveness, relevance and usefulness for the purposes of this narrative synthesis and research question. All included texts cited studies informing their theories and most also provided some study details. However, the quality of evidence was only reported in four texts (Karageorghis, 2008; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 2009), and none of the included texts clearly described study quality as a consideration that influenced or informed their theories (see Supplemental data for quality appraisal).

Data synthesis

References from the three theoretical contexts (therapeutic, sport and exercise, and auditory motor processing) were examined in an iterative process. All theories recognised a central theme, sub-cortical and cortical stimulation and response to music. From this central theme, two sub-themes emerged: (1) physiological arousal and (2) subjective experience. Physiological arousal included key concepts, entrainment or synchronisation resulting from the

Table 3. Characteristics of sports and exercise theories describing the modulating effects of music listening on exercise and physical activity.

Reference	Author discipline and publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Bishop (2007)	Doctoral thesis Sports and exercise	Designs: quant, qual; Participants: tennis players; Settings: nat, lab; Music: listening; PA: tennis; Measures: interview, questionnaires, reaction time, fMRI, TMS, EMG; Findings: selected variables in music impact experience and performance	Personal impact Positive affect Neurophysiological response Behavioural response	Music stimulates emotional pre-event response leading to behavioural readiness and ergogenic benefits
DeNora (2000)	Book Sociology	Designs: Ethnographic studies, interviews; Participants: Aerobics, karaoke, music therapy, retail; Settings: nat community; Music: listening and participation/performance; Measures: qualitative experience and observation; Findings: Music provides structural properties (or appropriations), which entrain with the physical body and influence emotions (affordances) during aerobics classes	Self-regulation Diversion Synchronisation/entrainment Emotional response Appropriation/affordance	Music is appropriated in everyday contexts, such as exercise classes, as a structural resource that affords emotional and physical responses
Harmon and Kravitz (2007)	Review Sports and exercise	Designs: qual, quant; Participants: exercise, impaired; Settings: nat, lab, rehab; Music: listening; PA: endurance, strength; Measures: physiological, performance, RPE; Findings: reduced fatigue, increased arousal and motor coordination	Reduced RPE Rhythmic Stimulation Neurophysiological response Enhanced performance	Music appears to be motivating during exercise and promotes performance and experience
Karageorghis et al. (2012)	Synopsis and recommendations Sports and exercise	Not specifically reported, but identified: Designs: reviews; Participants: sports, exercise; PA: endurance, strength; Measures: performance, psychological, RPE	Personal impact Rhythmic synchronisation Enhanced performance	Strategic music selection promotes psychological and psychophysical benefits leading to ergogenic effects

(*continued*)

Table 3. (*Continued*).

Reference	Author discipline and publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Karageorghis and Priest (2012a) (part 1)	Two-part review Sports and exercise	Designs: qual, quant; Participants: sports, exercise; Settings: nat, lab; music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: positive affect, reduced RPE, improved energy efficiency and work output	Rhythmic synchronisation Neurophysiological response Positive mood and affect Personal impact Reduced RPE Behavioural response	Pre- and in-task music with motivational qualities promotes psychological and ergogenic benefits
Karageorghis and Priest (2012b) (part 2)	Two-part review Sports and exercise	Designs: quant, qual; Participants: sports, exercise; Settings: nat, lab; Music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: positive affect, reduced RPE, improved energy efficiency and work output	Neurophysiological response Personal impact Reduced RPE Improved affect Enhanced performance Behavioural response	Music can exert beneficial psychological and ergogenic effects before, during and after exercise
Karageorghis (2008)	Book chapter Sports and exercise	Designs: quant, qual; Participants: Sports, exercise; Settings: lab, nat; Music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: physical psychological, physiological and ergogenic benefits	Personal impact Rhythmic synchronisation Reduced RPE Enhanced performance	Music with motivational qualities promotes psychological and ergogenic benefits during exercise
Karageorghis and Terry (2009)	Book chapter Sports and exercise	Designs: quant, qual; Participants: sports, exercise; Settings: lab, nat; Music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: physical psychological, physiological and ergogenic benefits	Positive mood Neurophysiological response Reduced RPE Rhythmic synchronisation Enhanced performance	Music with motivational qualities promotes psychological and ergogenic benefits during exercise

(*continued*)

Table 3. (*Continued*).

Reference	Author discipline and publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Karageorghis and Terry (1997)	Review aimed Sports and exercise	Designs: quant, qual; Participants: sports, exercise; Settings: lab, nat; Music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: reduced RPE and improved mood, affect and work output at low to moderate intensity exercise	Neurophysiological response Rhythmic synchronisation Improved mood Reduced RPE	Strategic music selection reduces fatigue, improves mood, facilitates arousal and entrains movement
Koc and Curtseit (2009)	Discussion paper Sport and exercise	Designs: quant; Participants: Sports; Settings: lab, nat; Music: listening; PA: endurance, strength, ball sports; Measures: performance, psychological, RPE, physical; Findings: enhanced performance, improved psychological and physiological parameters	Rhythmic synchronisation Reduced RPE Improved mood Neurophysiological response	Strategic music selection may improve exercise adherence and performance
Priest (2003)	Doctoral thesis Sports and exercise	Designs: qual, quant; Participants: sports; Settings: gym; Music: listening; PA: gym – endurance, strength; Measures: interviews, questionnaire, ergogenic, affect; Findings: motivational music increases work output but does not alter affect	Rhythmic stimulation Improved affect Personal impact Behavioural response	Music motivates as an input (stimulus), throughput (psychophysical) and output (consequence)

Notes: Quant = quantitative; qual = qualitative; obs = observational; nat = natural; lab = laboratory; PA = physical activity; fMRI = functional magnetic resonance imaging; TMS = transcranial magnetic stimulation; EMG = electromyogram; RPE = Ratings of perceived exertion.

Table 4. Characteristics of auditory-motor theories describing the modulating effects of music listening on exercise and physical activity.

Reference	Author discipline and publication details	Details of studies contributing to theory	Key concepts informing theory	Theory summary
Levitin and Tirovolas (2009)	Review Cognitive neuroscience	Not specifically reported, but identifies: Designs: neuroimaging and lesion studies; Participants: healthy, brain lesions; Music: participation, listening; Measures: fMRI, PET, ERP, MEG, behavioural observations	Subcortical/cortical Rhythm stimulation Neurophysiological response Behavioural response Emotional response Personal impact	Complex perceptual, cognitive and behavioural associations between music and cultural experience, and emotional and physical response
Todd et al. (2002)	Model Cognitive neuroscience	Not specifically reported, but identifies: Designs: neuroimaging and lesion studies; Participants: stroke; Music: participation, listening; Measures: PET	Subcortical/cortical Rhythmic stimulation Feedback/feedforward loop	Temporal tracking and beat induction involves the plant (body), sensory processing, planning and control, and movement execution
Zatorre et al. (2007)	Review Cognitive neuroscience	Not specifically reported, but identifies: Designs: neuroimaging and lesion studies; Participants: musicians, healthy, brain lesions, PD, stroke; Music: listening, participation; Measures: fMRI, MEG, TMS, behavioural observations	Subcortical/cortical Rhythmic stimulation Feedforward/feedback loop Neurophysiological response Emotional response Personal impact	Integration of auditory and motor information in several cortical and subcortical regions sequence, control, and correct movement

Notes: fMRI = functional magnetic resonance imaging; PET = positron emission tomography; ERP = event-related potentials; MEG = magnetoencephalography; TMS = transcranial magnetic stimulation.

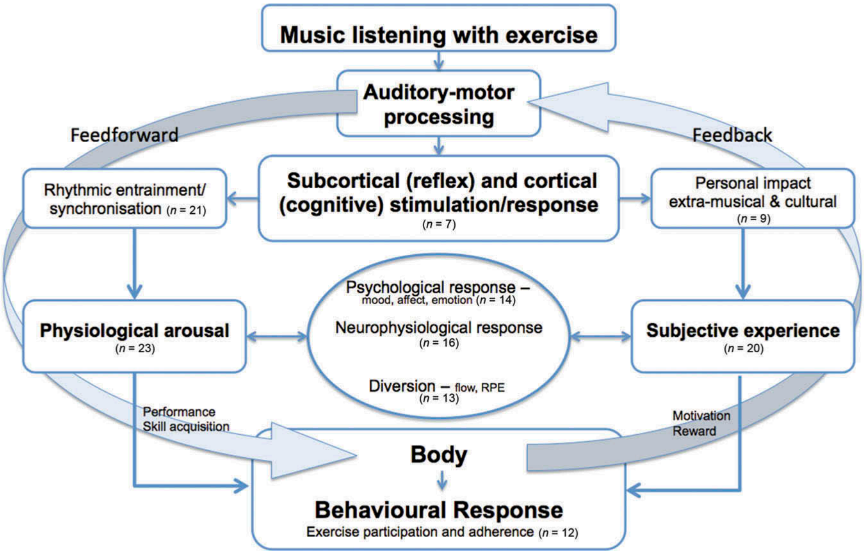

Figure 2. Meta-theory combining therapeutic, sports and exercise, and auditory-motor processing theories to describe the modulating effects of music listening on exercise and physical activity.

rhythmic stimulation in music, and neurophysiological responses to music as a whole. Key concepts underpinning subjective experience comprised personal impact, psychological response and diversion. These themes and concepts were implicated in a commonly held hypothesis, that physiological arousal and subjective experience impact behaviour response with increased exercise participation and adherence. A meta-theory incorporating theories from the three contexts, therapeutic, sports and exercise, and auditory-motor processing, was constructed to demonstrate how each of the identified major themes and each identified sub-theme, key concept and hypothesis contributed in answering the research question (Figure 2).

Discussion

Theories described the effects of music on cognitive processes as multifaceted and complex, involving unconscious subcortical and conscious cortical stimulation and response (Altenmüller & Schlaug, 2013; Levitin & Tirovolas, 2009; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Todd et al., 2002; Zatorre et al., 2007). Music mimics rhythms and patterns both within our bodies and externally in the environment, making it a resource that our brains readily recognise, interpret and understand. These stimulating effects of music on the human brain are so strong that ignoring music is more difficult than interacting with it (Levitin & Tirovolas, 2009; Todd et al., 2002; Zatorre et al., 2007). As such, music is a powerful resource that can be used to regulate intensities of physiological arousal and subjective experience to support exercise participation and levels of physical activity (Altenmüller & Schlaug, 2013; Bishop, 2007; DeNora, 2000; Harmon & Kravitz, 2007; Karageorghis, 2008; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997, 2009; Karageorghis et al., 2012; Koc & Curtseit, 2009; Levitin & Tirovolas, 2009; Murrock & Higgins, 2009; Paul & Ramsey, 2000; Priest, 2003; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut & Abiru, 2010; Thaut et al., 1999; Thaut & McIntosh, 1999; Todd et al., 2002; Zatorre et al., 2007).

Physiological arousal

All three theoretical contexts recognised that music can be used to manipulate states of physiological arousal. The human nervous system appears to be very sensitive to the rhythmic (tempo, pulse, beat), pitch (melody, harmony, tone) and dynamic elements in music (Altenmüller & Schlaug, 2013; Bishop, 2007; Levitin & Tirovolas, 2009; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut & Abiru, 2010; Zatorre et al., 2007). Schneck and Berger (2006) recognised that vibrations in music influence the entire body, from individual cells to organs and complex systems. This systemic influence of music on physiological arousal is usually unconscious (subcortical), involving entrainment with bodily rhythms such as walking, breathing, and heart rate, and biochemical changes that stimulate neurophysiological responses (Altenmüller & Schlaug, 2013; Levitin & Tirovolas, 2009; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut et al., 1999; Thaut & McIntosh, 1999; Todd et al., 2002; Zatorre et al., 2007)

Rhythmic entrainment

Exercise participants appropriate music as an external resource that helps them to synchronise movement patterns to meet expected situational demands (DeNora, 2000). The rhythmic properties of music provide an underlying steady pulse, which is interspersed at time intervals to cue pace, and is embedded with complex patterns such as syncopations and interjections to maintain interest (Altenmüller & Schlaug, 2013; Schneck & Berger, 2006; Thaut, 2005). While all the affording elements in music provide structural cues during exercise (DeNora, 2000), this rhythmic information was described as having a stronger influence on performance than pitch-related elements (melody, harmony, timbre) or lyrics (Karageorghis & Priest, 2012a, 2012b; Priest, 2003; Schneck & Berger, 2006; Thaut, 2005).

Complex processing involving integration between the auditory and motor systems leads to time organised movement patterns in response to rhythm in music (Levitin & Tirovolas, 2009; Schneck & Berger, 2006; Thaut, 2005; Thaut & Abiru, 2010; Todd et al., 2002; Zatorre et al., 2007). A feedforward, feedback loop, occurring over phases between consecutive musical beats cues and guides the full trajectory of each movement cycle (Levitin & Tirovolas, 2009; Rodriguez-Fornells et al., 2012; Thaut, 2005; Todd et al., 2002; Zatorre et al., 2007). Theories propose that the posterior auditory cortices and premotor cortices analyse the spectrum of sound and mediate cognitive processing in the cerebellum. The cerebellum appears to integrate this feedforward information with reference to memory and kinesthetic feedback to plan the execution of movement. Since the execution of movement occurs just before each consecutive beat, the feedforward/feedback loop allows for anticipation and fine adjustments in position, velocity and acceleration (Levitin & Tirovolas, 2009; Todd et al., 2002; Zatorre et al., 2007). This explains how repetitive human movement readily entrains or synchronises with consistent rhythmic patterns in music, and it is important to choose tempo and rhythm that support the desired exercise pace, rating and intensity (DeNora, 2000; Karageorghis & Priest, 2012a, 2012b; Karageorghis et al., 2012; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005) (Figure 3).

Theories propose that rhythm in music directly improves exercise performance. Rhythmic musical cues reduce variability in muscle recruitment, leading to improved symmetry, balance and motor coordination (Paul & Ramsey, 2000; Rodriguez-Fornells et al., 2012; Thaut, 2005; Thaut & Abiru, 2010; Thaut et al., 1999; Thaut & McIntosh, 1999). Similarly, exercising with synchronous music reduced oxygen consumption and increased exercise intensity and endurance compared with asynchronous music and no music conditions (Karageorghis, 2008; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997, 2009; Koc & Curtseit, 2009). Given these

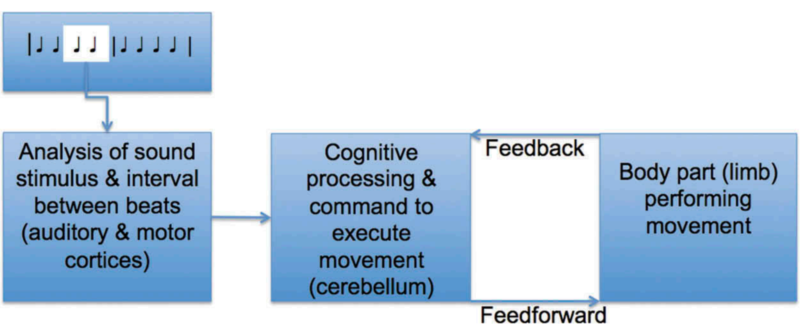

Figure 3. Rhythmic stimulation of motor movement and the feedforward/feedback loop.

findings, theorists proposed that rhythmic entrainment or synchronisation of repetitive movement cycles with music increases motor movement accuracy leading to improved energy efficiency and work output (time to exhaustion and exercise intensity).

Neurophysiological response

Multiple neurological processes have demonstrated responsiveness to the emotionally evocative qualities in music. Music excites and inhibits processes in the autonomic nervous system and can be used to regulate heart rate and blood pressure (Harmon & Kravitz, 2007; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997, 2009; Murrock & Higgins, 2009; Paul & Ramsey, 2000; Schneck & Berger, 2006; Thaut, 2005; Thaut et al., 1999). The neuroendocrine system is sensitive to emotional qualities in music composition along with extra-musical associations and stimulates the release of opioids, norepinephrine and neurotransmitters (dopamine and serotonin) leading to rewarding experiences and relief from discomfort (Altenmüller & Schlaug, 2013; Harmon & Kravitz, 2007; Murrock & Higgins, 2009; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005). The central nervous system reacts instantly to musical cues and responds to control muscle activation, motor movement, sensory perception, attention, and executive function (Altenmüller & Schlaug, 2013; Bishop, 2007; Koc & Curtseit, 2009; Thaut et al., 1999; Paul & Ramsey, 2000; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut & Abiru, 2010). Through these neurological processes, musical elements, tempo, harmony, melody and rhythm can be manipulated to excite and support high-energy activity with fast tempo and major key, or to calm and relax with slow tempo and minor key (Bishop, 2007; DeNora, 2000; Schneck & Berger, 2006; Zatorre et al., 2007).

Subjective experience

DeNora (2000) explained how individuals appropriate music to transform internal mood and energy levels so that they feel more motivated and energised during exercise. This influence of music was described as being dependent on intrinsic elements in the music (rhythm and musicality) and extrinsic factors resulting from extra-musical associations and cultural impact (Bishop, 2007; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997; Karageorghis et al., 2012; Koc & Curtseit, 2009; Levitin & Tirovolas, 2009; Priest, 2003; Thaut, 2005; Zatorre et al., 2007). Listening to strategically selected music that considers intrinsic and extrinsic factors improves subjective experience (mood and affect) during low-, moderate- and high-intensity exercise (DeNora, 2000; Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997; Karageorghis et al., 2012; Priest, 2003). Similarly, carefully chosen music interventions during rehabilitation are recommended to support mood and improve experience (Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005).

Personal impact

Familiar self-selected music with personally emotive qualities can alter behaviour (Schneck & Berger, 2006) and may maximise the positive influences of music during exercise (Karageorghis & Priest, 2012a, 2012b). The impact of music was affected by personal extrinsic factors including age, gender, personality traits, familiarity with the music, associations in the music with an event and cultural influence (Bishop, 2007; Priest, 2003; Schneck & Berger, 2006). In particular, age was implicated in changing the way music is appreciated with younger people preferring up-tempo loud music and older people preferring slower softer music (Priest, 2003). Attraction to a particular piece of music was also described as being dependent on the type of exercise being performed and the environmental context in which it is taking place (DeNora, 2000; Karageorghis & Priest, 2012a, 2012b; Schneck & Berger, 2006). Therefore, as described in theories from all perspectives, personal preference plays an important role in maximising the impact of music on exercise experience and performance.

Psychological response

Theories described the capacity of music to influence mood, affect and emotion during exercise. Intrinsic elements in music, including rhythm, tempo, harmony, melody and lyrics, were implicated as influential on the mood or emotional feel of the music, with pitch-related elements having the strongest effect and lyrics also offering impact (Bishop, 2007; Karageorghis & Priest, 2012a, 2012b; Priest, 2003; Schneck & Berger, 2006; Thaut, 2005; Zatorre et al., 2007). In general, up-tempo music with wide range in pitch, syncopated rhythms, major harmonic structure, and motivating lyrics is likely to excite and support high-energy activities. Alternatively, music with slow tempo, minimal melodic range, few or no lyrics, and consistent rhythm, instrumentation and harmonic structure might be perceived as relaxing (Zatorre et al., 2007).

Diversion

Music listening during exercise was described as a dissociative cognitive strategy that diverts attention away from internal experiences of pain and discomfort (Altenmüller & Schlaug, 2013; DeNora, 2000; Murrock & Higgins, 2009; Paul & Ramsey, 2000; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005). Similarly, music was found to increase experiences of flow and reduce boredom during repetitive tasks, particularly when the music was self-selected and rated as motivating by the exercise participant (Karageorghis, 2008; Karageorghis & Terry, 1997; 2009; Karageorghis & Priest, 2012a; 2012b; Koc & Curtseit, 2009; Priest, 2003). DeNora (2000) explained this as an affordance in music that changes experiences of time and alters bodily self-perceptions to best meet the expected demands of a given situation.

Those authors writing from sports and exercise contexts discussed the capacity of music to divert from feelings of discomfort and fatigue as reducing ratings of perceived exertion (RPE). Reduced RPE with music was evident during low- to moderate-intensity exercise but not at high-intensity exercise. Sports and exercise theorists proposed that music is unable to divert attention beyond a certain threshold of exercise intensity when perceptions of bodily discomfort are stronger (Karageorghis & Priest, 2012a, 2012b). Nonetheless, while RPE at high intensity were the same with or without music, exercise participants still experienced more positive mood profiles during music conditions at all exercise intensities, suggesting that even though they knew they were exercising hard, they were happier about it. Theories from sports and exercise contexts also noted that untrained exercise participants were more susceptible to the diversion effects of music than elite athletes, proposing that trained athletes were practiced in diverting attention from physiological discomfort in any situation and were less likely to be impacted by music (Karageorghis & Priest, 2012a, 2012b).

Behavioural response

Theories proposed that the capacity in music to facilitate physiological arousal and improved subjective experience during exercise could lead to behavioural changes with increased exercise participation and adherence. Persistent physiological arousal resulting from rhythmic entrainment or synchronisation improves exercise performance and facilitates the acquisition of motor skills, leading to a sense of accomplishment and increased confidence (Altenmüller & Schlaug, 2013; Bishop, 2007; Karageorghis & Priest, 2012a, 2012b; Koc & Curtseit, 2009; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006; Thaut, 2005; Thaut et al., 1999). It was also suggested that rewarding subjective experiences associated with the production of neurotransmitters, dopamine and serotonin, during conditions with music and exercise might facilitate learning and neuroplastic change (Altenmüller & Schlaug, 2013; Rodriguez-Fornells et al., 2012; Schneck & Berger, 2006). From a social perspective, music was described as a resource that affords incentives during exercise such as motivation, vigour, coordination, and endurance, thereby promoting bodily, emotional and behavioural engagement (DeNora, 2000).

While in most cases behavioural change leading to increased exercise participation and adherence was posed as a conclusion or hypothesis, qualitative evidence was presented indicating that music influences gym attendance and exercise adherence (Karageorghis & Priest, 2012a, 2012b; Priest, 2003). This hypothesis has important consequences about the use of music during exercise, as interventions that increase exercise participation, adherence and levels of physical activity might improve public health (Warburton et al., 2006; Wen et al., 2011). However, it appears that further research is required to support this hypothesis.

Meta-theory

The modulating effects of music listening on health-related exercise are multi-faceted with theories from different disciplinary contexts describing similar inter-related influences, which we have interpreted as themes, concepts and a hypothesis to support our meta-theory. Our meta-theory recognises that music listening stimulates multiple subcortical and cortical responses during exercise. These cognitive processes give rise to two broadly classified influences, physiological arousal and subjective experience, which are hypothesised as having a positive impact on behavioural response with increased exercise participation and adherence.

Physiological arousal is mediated by the effects of rhythmic stimulation on the human brain, and neurophysiological responses resulting from the impact of music as a whole on the autonomic nervous system, neuro-endocrine system and central nervous system. Rhythm and tempo are particularly important as entrainment or synchronisation with rhythmic phases in the music stimulates cortical and subcortical processes that support motor coordination and control. Individual trials support this association between rhythm and tempo with physical activity and exercise. Phillips-Silver and Trainor (2007) demonstrated that different patterns of repetitive bodily movements influence how we encode ambiguous rhythm, thereby illustrating the strong impact of limb feedback during exercise. Influences of rhythm and timbre in music were also examined using motion capture, providing evidence that bodily movements anticipate and mirror characteristics in music (Burger et al., 2013). Further, humans appear to have a predisposition for repetitive movement at cadences around 120 beats per minute, a tempo that is commonly reflected in popular Western music (MacDougall & Moore, 2005). Theorists believe that bodily perception and response to these rhythmic qualities in music during exercise leads to improved energy efficiency, exercise performance and skill acquisition.

Subjective experience is dependent on the personal impact derived from extra-musical associations to a particular piece of music, and the intrinsic qualities within the composition of the music (rhythmic and pitch-related elements). If chosen with care, these extrinsic and intrinsic qualities of music can be manipulated to positively influence mood, affect, emotional response and cognitive thought processes, further stimulating physiological arousal. In support of this notion, individual trials have identified preferred characteristics in music that have an impact physical response. Kornysheva et al. (2010) found that premotor activity is heightened when beat is preferred. Further, tempo preferences slow as we age, and capacity to entrain with non-preferred tempo is more challenging for older adults (McAuley et al., 2006). Theorists hypothesise that attention to these personal preferences in music selections will facilitate improved exercise performance and enjoyment, resulting in behaviour change with increased exercise participation and adherence.

The meta-theory demonstrates several associations that could be used to generate hypotheses for research. For example, it suggests that music listening increases physiological arousal and positive subjective experience, and together these two factors might have an impact on amounts of exercise participation and adherence. Therefore, research might aim to compare the relative contributions of physiological arousal and subjective experience on changes in exercise behaviour. Further hypotheses might test the effects of music listening during exercise on subcortical and cortical responses in relation to rhythmic entrainment or personal impact; or the influence of neurophysiological, psychological and diversion factors on physiological arousal and subjective experience. Such research might be tested with populations who are at risk of, or demonstrate long-term sedentary behaviour patterns, for example, older adults, those attending rehabilitation programmes, and people with cardiovascular disease (Haskell et al., 2007; Nelson et al., 2007; Peiris, Taylor & Shields, 2013). Given the suggested associations, and the lack of evidence describing music listening as an intervention for exercise and physical activity with vulnerable populations (Clark, Taylor & Baker, 2012), further research using theoretically supported hypotheses are warranted.

The meta-theory could also be applied as a framework to inform music therapy practice. Given that music listening may increase exercise adherence and participation, leading to increased physical activity levels with potential benefits to public health, music therapists might prescribe music listening with exercise as a preventative or health promotion intervention for people in medical and community contexts. In accordance with the meta-theory, music therapists would pay attention to qualities in music selections that promote physiological arousal and positive subjective experiences for individual participants and particular exercise situations. For example, music playlists would aim to match the timing of repetitive movements in exercise with rhythmic, tempo and pulse. Music therapy assessments would ensure that individual exercise participants perceive the music selections as motivating for the particular types of exercise being performed. Populations who might benefit include those in programmes where a major aim is to increase physical activity levels, such as in cardiac and respiratory rehabilitation (Haskell et al., 2007; Nelson et al., 2007).

Dance is recognised in psychological and physiological therapies as exercise capable of preventing chronic disease and promoting health (Kreutz, 2008; Quiroga Murcia et al., 2009). However, the current review did not include theories describing dance, and this omission could be considered a limitation. The purpose of this review was to clearly focus on the modulating effects of music alone as a primary intervention for everyday recreational exercise involving simple repetitive movement, such as walking. Given the intimate associations between movements in dance with music, we felt that dance theories might describe a different and more complex phenomenon.

In conclusion, this review of 23 theories provides support for a hypothesis that music listening during exercise might increase exercise participation and adherence. Music listening is accessible, inexpensive and convenient, making it an intervention that meets recommendations for exercise compliance and lifestyle change (Brawley, Rejeski & King, 2003; Sniehotta, Scholz & Schwarzer, 2006). Music therapists are ideally placed to implement and investigate music listening as an intervention for increasing levels of physical activity. Given that sedentary behaviour is recognised as a leading contributor to global mortality (World Health Organisation, 2010), high-quality informed research and the further development of theories that clearly establish clinical guidelines to maximise the influences of music on exercise participation and adherence across various populations might make a significant contribution.

Supplemental data

Supplemental data for this article can be accessed here.

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