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Musical meaning modulates word acquisition

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ABSTRACT

Musical excerpts have been shown to have the capacity to prime the processing of target words and vice versa, strongly suggesting that music can convey concepts. However, to date no study has investigated an influence of musical semantics on novel word acquisition, thus corroborating evidence for a similarity of underlying semantic processing of music and words behaviourally. The current study investigates whether semantic content of music can assist the acquisition of novel words. Forty novel words and their German translation were visually presented to 26 participants accompanied by either semantically congruent or incongruent music. Semantic congruence between music and words was expected to increase performance in the subsequent forced-choice recognition test. Participants performed significantly better on the retention of novel words presented with semantically congruent music compared to those presented with semantically incongruent music. This provides first evidence that semantic "enrichment" by music during novel word learning can augment novel word acquisition. This finding may lead to novel approaches in foreign language acquisition and language rehabilitation, and further strongly supports the concept that music has a strong capacity to iconically convey meaning.

1. Introduction

Acquiring a new language, including its vocabulary, can be a challenging and often strenuous task. A large body of research has focused on the question of how second language acquisition can be facilitated. Ranging from specific mnemonic techniques to specific presentation and arrangement of learning material, a great number of different strategies—varying in their effectiveness—have been investigated (Khoii & Sharififar, 2013; Ludke, Ferreira, & Overy, 2014; Wei, 2014). These cognitive strategies include for example recurrent repetition (i.e. "rote memorization"), note taking, contextualization (O'Malley & Chamot, 1990), semantic mapping, in which semantically close words are presented together visually (Khoii & Sharififar, 2013), imagery (e.g. using key words or the "hook technique"; Paivio & Desrochers, 1981) as well as rhythmic speaking or singing (Ludke et al., 2014). Inspired by the observation that lyrics learned with children's songs early in life seem to be robustly retained in long-term memory, some researchers proposed a memory-enhancing effect of music on verbal memory (Calvert & Tart, 1993; Rainey & Larsen, 2002; Simmons-Stern, Budson, & Ally, 2010).

However, effects of music on verbal learning and memory as reported in the literature are divergent. Whereas some studies report an enhancing effect of music on verbal learning and semantic memory tasks (de Groot, 2006; Ferreri, Aucouturier, Muthalib, Bigand, & Bugaiska, 2013; Kang & Williamson, 2013), others report no or even negative effects on performance (Jäncke & Sandmann, 2010; Verga, Bigand, Kotz, Verga, & Sciences, 2015). A number of findings from patients with neurodegenerative diseases or from patients after stroke indicate a positive effect of music on language learning, semantic memory performance, verbal memory, and other language-related skills (Baur, Uttner, Ilmberger, Fesl, & Mai, 2000; Särkämö et al., 2008, 2014; Simmons-Sternet al., 2010; Thaut & McIntosh, 2014). Reports on positive effects of music on aspects of learning are further corroborated by studies investigating a positive influence of musical training on novel word learning in children and adults (Dittinger et al., 2016; Dittinger, Chobert, Ziegler, & Besson, 2017), demonstrating that early music training can facilitate later foreign language learning.

In the current study we addressed a novel method how second language acquisition may be facilitated based on previous findings investigating the N400 as an indicator of semantic proximity. Music has previously been shown to have the capacity to effectively prime the processing of target words. This was shown to be similarly efficient to using sentences as primes, as shown in an ERP study using the N400 as a marker of lexico-semantic access (Koelsch et al., 2004). Interestingly,

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a reverse influence has also been reported, where linguistic context has been shown to prime conceptual processing of musical excerpts, as reflected in a larger N400 in response to conceptually unrelated word-music pairs (Daltrozzo & Schön, 2009).

Furthermore, the capability of music to inter-individually convey extra-musical meaning has been shown for different domains, including affect (Steinbeis & Koelsch, 2011), representations of movement concepts (Zhou, Jiang, Wu, & Yang, 2015), and images of spatial scenes (Zhou, Jiang, Delogu, & Yang, 2014), and certain emotional expressions (Fritz et al., 2009). Note however that a different geographical and cultural environment may lead to differences in semantic association profiles when listening to music. This seems to suggest a dominance of certain cultural associations over iconic meaning (Fritz, Schmude, Jentschke, Friederici, & Koelsch, 2013).

Evidence from PET and EEG studies suggests that verbal semantic memory and semantic memory for music and sounds activate partly overlapping neuronal networks (Cummings et al., 2006; Groussard et al., 2010). This may suggest that concurrent activation of both systems during a learning task (possibly in association with higher levels of arousal) leads to deeper processing and consequently to an enhanced learning effect. In the current study, we investigated whether semantic content of music can be used to assist novel word acquisition. To this end, we presented participants with novel words derived from a foreign language and visual presentation of these words was accompanied by either semantically congruent musical stimuli or by semantically incongruent musical stimuli (e.g. the word “wideness” together with music-evoking associations of wideness or narrowness).

Congruence in meaning of music and the novel word was expected to increase learning outcome in terms of lower error rates and shorter times to response in the test phase. An effect of congruence between music and word meaning on vocabulary learning would also support the notion that music stimulates representations of verbal semantic concepts.

2. Methods

2.1. Participants

Twenty-eight healthy volunteers participated in the study, who had been listed in the Max Planck Participant Archive as having normal hearing. However, two of the participants in a post-experimental assessment showed a recent development of hearing impairments and were as a consequence excluded post-hoc. The remaining 26 participants (17 females, age 25.85 ± 3.65, range: 21–33) were native Germans and had no previous experience with the Indonesian language. They had normal or corrected to normal vision, no history of dyslexia, or any chronic neurological or other disease, and were not taking any CNS active medication. Participants gave written informed consent and were financially compensated for their participation. The experiment was approved by the Ethics Committee of the University of Leipzig.

Apart from demographical data (age, sex), exclusion criteria (dyslexia, hearing or visual impairments), musical expertise (musical experience in years), and second language skills (self-reported level of proficiency) were assessed via a questionnaire.

2.2. Stimuli

2.2.1. Verbal stimuli

Forty German nouns (1–3 syllables; mean = 1.75;) referring to concrete entities (e.g. ‘needle‘) or abstract concepts (e.g. ‘loneliness’) were used (see Appendix A for full list). Mean log frequency of the nouns was 2.781 (SD = 0.701; SUBTLEX-DE corpus; Brysbaert et al., 2011). There was no difference in log frequency between German nouns that were paired with an Indonesian word and semantically related musical passage (M = 2.993; *SD* = 0.550) and German nouns that were paired with an Indonesian word and semantically unrelated musical passage (Brysbaert et al., 2011). These nouns were taken from a previous study by Fritz et al. (2013) where their semantic association with certain musical pieces was demonstrated. Each of the German words was paired with a pseudoword derived from its Indonesian translation. The existing Indonesian word was manipulated to avoid confounds introduced by differences in phonologic structure: All words were reduced to two syllables and always started and ended with a consonant. The pseudo-Indonesian words were adjusted in phoneme-grapheme conversion in line with standard German orthography and followed German phonotactic constraints (e.g. /PERAYAAN/ *Engl.:* ‘party’, was presented as /PERJAN/). To avoid phonological priming, word-onset was altered if the German word and its respective pseudo-Indonesian translation started with the same phoneme and similarity between them was avoided. All (pseudo)words were presented in white capital letters on a black background in Times New Roman 46pt. The German word was always presented on the left and the pseudo-Indonesian word on the right side of the display.

2.2.2. Musical stimuli

Stimuli were taken from a selection of musical excerpts from previous experiments that had through behavioral testing been associated with a word pair that was rated to have a good semantic fit (Fritz et al., 2013; Koelsch et al., 2004). For this a large selection of prime-target items had been constructed, where for each target word related and unrelated words were presented simultaneously on a screen. Participants were asked to rate the degree of semantic fit between the prime and each of two target words on an 11-point scale ranging from −5 (semantically strongly unrelated) to +5 (semantically strongly related), leading to two ratings for each prime. For each prime, t-tests were used to identify whether these ratings differed significantly from each other. Non-significant items were discarded (Koelsch et al., 2004). These stimuli were excerpts from instrumental pieces in the tradition of classical orchestral music, e.g. an excerpt from “The Moldau” by Bedřich Smetana (1882) was used as the semantically congruent counterpart for the German noun /BACH/ (*engl.*:‘stream’). Twenty musical pieces were selected that had been demonstrated to be associated with 20 (i.e. half) of the German nouns. For the purpose of this study, all excerpts were cut to a duration of 8 s. They were presented at 70 dB from loudspeakers behind the computer screen. The names of the musical pieces and the composers are listed in Appendix A.

2.3. Procedure

Prior to the ***training phase*** a verbal instruction was given to memorize presented word pairs, which consisted of one German and one pseudo-Indonesian word. Stimuli were presented in two blocks. Within each block, each of 40 word pairs (German/pseudo-Indonesian) was presented once. Each musical stimulus was presented four times in total, twice within each block. For half of these pairs the semantically related musical stimulus was played during the visual presentation of the German and the novel pseudoword. The other half of the word pairs was presented with a semantically unrelated musical passage. Within each block, stimulus configurations were presented in a randomized order. The design is illustrated in Fig. 1. Note that for all novel pseudo-Indonesian words a verbal association with the German root word was established; the difference of interest was whether this pairing was accompanied by a semantically related or unrelated musical passage.

In the subsequent ***test phase***, German nouns were visually presented in isolation at the top of the screen and participants performed a forced-choice task comprised of 6 pseudo-Indonesian words presented at the bottom of the screen. The pseudo-Indonesian distractors as well as the positions of target and distractor words were pseudorandomized. Hence, pseudo-Indonesian target words occurred equally frequently in the six possible positions. The resulting displays were presented in randomized order. There was no explicit time constraint but participants were advised not to ponder too long before making their forced

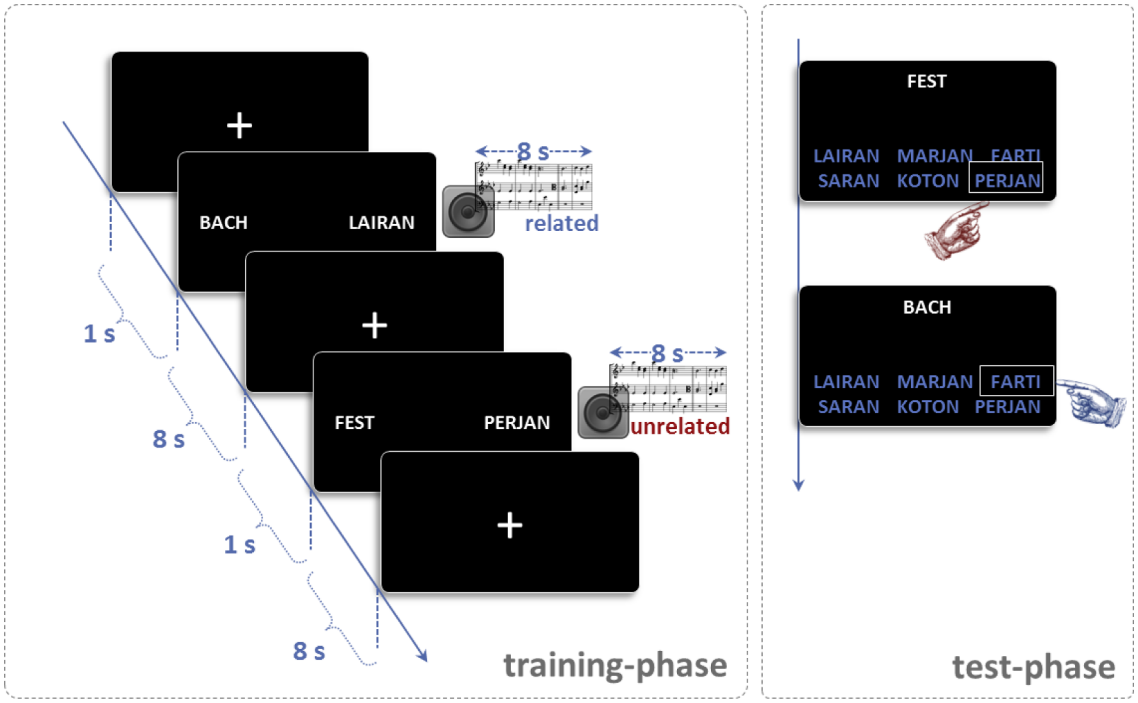

Fig. 1. Experimental set-up. During the learning phase (left), participants were instructed to focus on the fixation cross for 1 s before each trial. Subsequently, German ↔ pseudo-Indonesian word pairs were visually presented accompanied by either a semantically related or unrelated musical excerpt of 8 s. During the *test phase* (right) participants performed a forced-choice task from a selection of 6 pseudo-Indonesian words to the German root word at the top of the screen (here /BACH/, engl.: 'stream'). There was no time constraint for this task.

choice. The *time to response* measured in the current study is thus different from what it classically measured as *reaction time*, where a time constraint is introduced as part of the response, and values measured in the current study should thus not be compared to reaction times measured in previous studies. Participants responded via keyboard. Correct answers time to response were recorded.

2.4. Statistical analysis

Paired sample t-tests were used to test for differences between experimental conditions and the length of response times for correct vs. incorrect answers. Potential sex differences were explored via a Student's *t*-test. All correlations were calculated using Pearson's method. Where applicable, significance thresholds were corrected for multiple comparisons through the Bonferroni method.

3. Results

Descriptive statistics are shown in Table 1. An error analysis revealed significant differences between number of errors of words learned during congruent compared to semantically incongruent musical stimulus presentation, paired $t(25) = -2.79$, $p = .01$, CI $[-2.54, -0.38]$, d[1] $= -0.55$. On average, participants made 1.46 ($SD = 0.52$) fewer errors in the test phase when words were presented with their semantically corresponding sounds in the learning phase (Fig. 2; Table 1). Further, participant's mean time to response were significantly shorter for stimuli learned with semantically congruent music compared to stimuli learned with semantically incongruent music, paired $t(25) = -3.27$, $p = .003$,[2] CI $[-1605, -364.5]$, $d = -0.79$ (Fig. 3). Overall, participants' times to

Table 1
Means and standard deviations of response errors and response times for congruent/incongruent stimulus presentation in the learning phase. Response times are reported in milliseconds.

	Mean (SD)		
	Incongruent	Congruent	Total
Errors	7.73 (4.45)	6.27 (4.12)	14 (8.15)
Response time overall	7902 (2960)	6918 (2042)	7410 (2424)
Response time correct	7092 (2785)	6050 (1604)	6470 (2058)
Response time incorrect	10,324 (4708)	9716 (3714)	10,362 (3950)

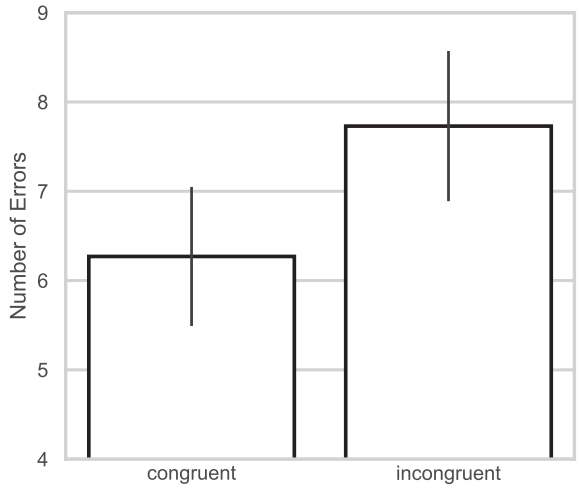

Fig. 2. Average number of errors made in the test phase for semantically congruent vs. semantically incongruent presented stimuli. Error bars indicate Standard Error.

[1] All Cohen's *d* reported on paired t-tests corrected for dependency of means with the method suggested by Morris and DeShon (2002).

[2] Survived significance testing after Bonferroni correction for multiple comparisons ($\alpha = 0.0125$).

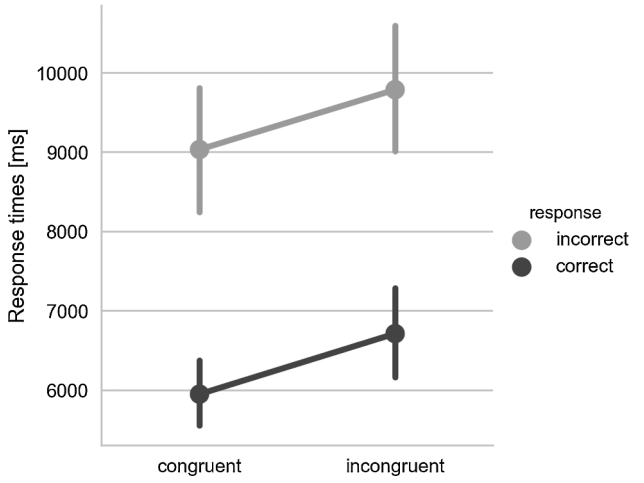

Fig. 3. Average times to response (in ms) for correct and incorrect responses in the test phase for semantically congruent vs. semantically incongruent presented stimuli. Error bars indicate 95% confidence intervals.

response were significantly shorter when their answers were correct than when they were incorrect, paired $t(25) = -5.95$, $p < .001$,[3] CI $[-5240, -2544]$, $d = -1.34$. Number of errors during the test phase and response times did not differ between sexes ($p > .43$ and $p > .86$, respectively). Moreover, number of errors and response times did not correlate with age ($r < 0.01$, $p > .99$ and $r = 0.18$, $p > .37$, respectively). Additionally, no correlation was found between musical expertise (musical experience in years) and number of errors ($r < -0.01$, $p > .98$) or response times ($r = 0.23$, $p > .42$).

4. Discussion

The present study investigates effects of musical semantics on novel word learning. Presenting the novel pseudo-Indonesian words and their German translations in the presence of musical stimuli, which were either congruent or incongruent with the word's meaning, we demonstrate that congruent musical and verbal semantics increased the learning effect. This was reflected in lower error rates and also corresponded to shorter times to response in the test phase.

Our finding that a musical stimulation of semantic networks facilitates the acquisition of novel word forms are in line with previous studies suggesting that music and speech functions rely on shared neural representations that are similarly involved in speech and music (Besson, Chobert, & Marie, 2011; Cummings et al., 2006; Daltrozzo & Schön, 2009; Groussard et al., 2010; Hoch, Poulin-Charronnat, & Tillmann, 2011; Jäncke, 2012; Koelsch, 2011; Ott, Langer, Oechslin, Meyer, & Jancke, 2011; Patel, 2011; Peretz, Nguyen, & Cummings, 2011; Schön & Francois, 2011; Shahin, 2011; Steinbeis & Koelsch, 2008; Strait & Kraus, 2011; Tallal & Gaab, 2006). The current findings also correspond to previous studies suggesting reciprocal priming effects of musical semantics and verbal semantics (Daltrozzo & Schön, 2009; Koelsch et al., 2004; Steinbeis & Koelsch, 2011; Zhou et al., 2014, 2015). Using the N400 as an indicator of semantic proximity has been proven to be a very powerful tool to examine a correspondence of meaning in music and word meaning (Daltrozzo & Schön, 2009; Koelsch et al., 2004). However, a substantial number of experts do not agree that N400 studies with music conclusively prove that music conveys semantic concepts in a similar way to how words convey semantic concepts, because the N400 is a neural event that corresponds to a variety of processes including perception, attention, memory, and language (Kutas & Federmeier, 2011) and may not exclusively be an indicator of semantic processing. The current study, showing that a variation of semantic proximity of simultaneously presented music during word learning systematically modulated learning success for the first time provides strong behavioral evidence for a similarity of neural processing of music and words.

Notably, such a stimulation of semantic concepts through music may partly (but probably not conclusively) underlie some beneficial effects of music listening, for example as part of a rehabilitation process in stroke patients (Särkämö et al., 2008). It may further be argued that to some degree repeated stimulation of semantic concepts during musical training may also correspond to the positive influence of previous musical training on novel word learning facilitating foreign language learning, which has been shown for children and adults (Dittinger et al., 2016, 2017).

While a positive effect of semantic enrichment on learning has been shown for other extra-linguistic stimuli (e.g. Feyereisen, 2006; Krönke, Mueller, Friederici, & Obrig, 2013; Macedonia & Knösche, 2011), this is the first report of a facilitatory effect of musical meaning on word acquisition. Here we argue that activation of an additional semantically related representation through listening to semantically rather congruent music during word learning may thus have created a stronger semantic memory trace between the known and the novel word. Note that because musical excerpts were not presented during the test phase they would not cue the correct word. Thus the improved recognition of words learned with congruent musical stimuli cannot be explained by enhanced context-dependent memory (Godden & Baddeley, 1975).

The training procedure investigated in the current study was relatively short and included only one repetition of the novel word. Because this relatively short procedure already led to marked differences in performance during the test phase, this may suggest a relevance of the current paradigm to both foreign language acquisition and language rehabilitation. It should be noted though that the current design does not allow to disentangle whether the difference between the two learning contexts is driven by an enhancing effect of meaning congruence between musical and verbal material, an inhibiting effect on verbal learning performance by semantically incongruent musical stimuli (such that the subjects might have experienced more difficulties to learn the word when they are presented simultaneously with music that is perceived as incongruous), or a combination of both.

Here we would also like to consider and discuss the possibility of different explanations for the current findings. For example, it is probable that different arousal levels induced by music the subjects know and don't know would induce dopamine and/or glucocorticoid depletion that as an effect positively influence memory consolidation. However, because in the current design the same musical excerpts were used for music-word-pairs that were semantically related and such that were semantically unrelated, such arousal effects should be balanced out, and would not have systematically influenced the current results.

The current findings might also be interpreted in terms of episodic memory processes such that episodic memories associated with the musical excerpts rather than their iconic extra-musical meaning might have modulated memory strength of music-word pairs through a systematic difference in the amount of more similar sources (specific experiences) associated with the musical excerpts. For example, if a musical piece closely associated with the word sunshine would have been more often in life been associated with experiences such as weddings, parties, friendship, holiday, then it might through these previous experiences with the musical piece rather than through its semantic properties correspond to a brain representation that overlaps with that of the word sunshine. Note however, that while such episodic memories may thus have an influence on the semantic network associated with the musical piece, this would probably only be the case because the iconic meaning of the musical excerpt would systematically determine the quality of experience that people would likely have had in association with hearing the respective excerpt.

[3] Survived significance testing after Bonferroni correction for multiple comparisons ($\alpha = 0.0125$).

The current study had some limitations that should be improved in future experiments. In the Results section we report that a significant difference in performance between the two experimental conditions was observed not only for overall accuracy but also for time to response. Note however that because participants hat not been instructed to respond as fast as possible and there was no explicit time constraint we here did not record what is typically called "Reaction Times" in the literature, using the classic instruction: "Please press one of the two buttons as fast as possible while making as few errors are possible". This would explain the relatively long average time to response, which can be argued to be too long to be informative and to be comparable to previous reaction time experiments. In a future variation of the research paradigm we therefore suggest to preferably stick to a classical reaction time parameter, introducing a time constraint during the response.

Two participants had to be excluded post-hoc after being invited to participate in the study because they had lately been experiencing hearing impairments, which had previously not been assessed and indicated in the participant data base. In a future study it would certainly be more appropriate to test for hearing impairments before, rather than after inviting participants to the study.

In future studies, the current music-supported learning paradigm could also be compared to other learning paradigms not systematically based on congruency of associations between music and verbal content. Furthermore, the current paradigm could be investigated with varied parameters, such as investigating long-term memory of acquired vocabulary in a longitudinal design, increasing the number of words to be learned, varying the level of L2 proficiency in learners, and investigating free recall performance. With respect to further improving the current research paradigm it may be desirable to balance congruent and incongruent pairings across two lists so that all German nouns/Indonesian pseudo-words are paired once with congruent music and once with incongruent music with an equal number of words and musical excerpts so as to avoid repetitions, which could possibly bias the results.

In conclusion, the current study provides first evidence that music listening can systematically modulate the encoding strength of novel word forms, probably by stimulating representations of semantic content that are shared with the verbal modality. We demonstrate a method to systematically modulate learning performance of vocabulary with respect to error rate, a tool that may be beneficial to foreign language acquisition and language rehabilitation.

5. Statement of significance

This study demonstrates that word acquisition can systematically be improved through a novel type of music supported learning, where concurrent presentation of novel words with music perceived as semantically congruent increases acquisition performance. The study also for the first time unambiguously shows that music listening corresponds to semantic processing.

Acknowledgements

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Appendix A

See Table 2.

Table 2
List of musical stimuli. Excerpts only included instrumental parts of the musical pieces.

Musical excerpt	Composer	Title
Farewell	Alasdair Mitchell	English Pastoral Impressions, Op. 26: III, "Over The Hill And Far Away – Allegro Moderato"
Arrival	Dmitri Shostakovich	Festival Overture, Op.96; performed by the Royal Philharmonic Orchestra
Stream	Bedřich Smetana	Ma Vlast – 2. Vlatava (My Country; The Moldau); performed by Rafael Kubelik & Boston Symphony Orchestra
Danger	Franz Liszt	Totentanz
Loneliness	Zbigniew Preisner	Reprise (Closing Credits Version)
Bird	Camille Saint- Saëns	The Carnival of the Animals
Celebration	Wolfgang Amadeus Mozart	Sinfonia in D Major "Die Bauernhochzeit" – 5. Finale; Molto Allegro (Peasant Wedding); performed by Ensemble Eduard Melkus & Eduard Melkus
Fire	Igor Strawinsky	Der Feuervogel
Dance	Carl Maria von Weber	Der Freischütz; performed by Dresden Staatskapelle
Bull	Pjotr Iljitsch Tchaikovsky	Swan Lake, Op. 20, Act 3: 21. Spanish Dance (Allegro non troppo: tempo di bolero); performed by London Symphony Orchestra
Joy	Jules Massenet	La Traviata, Act 1; performed by Anna Netrebko
Peace	Johann Sebastian Bach	Was mir behagt ist die muntre Jagd; BWV 208 "Hunt Cantata"; performed by Edith Mathis & Peter Schreier & Berlin Chamber Orchestra
Morning	Alexander Borodin	In the Steppes of Central Asia; performed by Philharmonic Hungarica & Othmar Maga
Poison	Francis Poulenc	La Dame Aveugle; performed by Francois L Roux, Pascal Roge, Soloistes De L'Orchestre National De France & Charles Dutoit
Water	Maurice Ravel	Jeux d'eau; performed by Werner Haas
Hero	Ludwig van Beethoven	Overture "Egmont", Op. 84; performed by Gewandhausorchester Leipzig & Kurt Masur
Sadness	Edvard Grieg	Peer Gynt Suite No. 1, Op. 46: II. Ase's Death (Andante Doloroso); performed by Leonard Bernstein
Hunt	Richard Wagner	Götterdämmerung Act 3; "Trink, Gunther, Trink"; performed by Wolfgang Windgassen, Thomas Stewart, Josef Greindl & Orchestra of the Bayreuth Festival
Fight	Igor Stravinsky	Part II: The Sacrifice – Glorification of the Chosen One; performed by Simon Rattle & National Youth Orchestra Of Great Britain
King	Henry Purcell	The Cebell; performed by Maurice Andre

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bandl.2018.12.001.

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