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# The emotional effect of background music on selective attention of adults

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12 **Keywords: selective attention, inhibition, Stroop task, background music, musical**  
13 **emotions, background noise, arousal, neuropsychology.**

14

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16

17

18 **ABSTRACT**

19 Daily activities can often be performed while listening to music, which could influence the  
20 ability to select relevant stimuli while ignoring distractors. Previous studies have established that  
21 the level of arousal of music (e.g., relaxing/stimulating) has the ability to modulate mood and  
22 affect the performance of cognitive tasks. The aim of this research was to explore the effect of  
23 relaxing and stimulating background music on selective attention. To this aim, 46 healthy adults  
24 performed a Stroop-type task in five different sound environments: relaxing music, stimulating  
25 music, relaxing music-matched noise, stimulating music-matched noise, and silence. Results  
26 showed that response times for incongruent and congruent trials as well as the Stroop  
27 interference effect were similar across conditions. Interestingly, results revealed a decreased  
28 error rate for congruent trials in the relaxing music condition as compared to the relaxing music-  
29 matched noisecondition, and a similar tendency between relaxing music and stimulating music-  
30 matched noise. Taken together, the absence of difference between background music and silence  
31 conditions suggest that they have similar effects on adult’s selective attention capacities, while  
32 noise seems to have a detrimental impact, particularly when the task is easier cognitively. In  
33 conclusion, the type of sound stimulation in the environment seems to be a factor that can affect  
34 cognitive tasks performance.

35 **INTRODUCTION**

36 Music is considered among the most enjoyable and satisfying human activities (Dubé & Le Bel,  
37 2003). The recent development of portable players with unlimited access to musical libraries  
38 means that people’s access to music has never been greater than in the last decade (Krause et al.,  
39 2014). Adults listen to music for an average time of 17.8 hours per week [International  
40 Federation of the Phonographic Industry, 2018]. It is therefore possible to infer that most adults

41 perform a large part of their daily tasks in the presence of background music (cooking, driving,  
42 working, studying, etc.). The efficient accomplishment of these tasks recruits the capacities of  
43 selective attention, also referred as attentional control; the cognitive ability to select, among a  
44 considerable load of information, relevant stimuli while inhibiting others (Murphy et al., 2016;  
45 Bater & Jordan, 2020). Due to their front-line role in information processing, selective attention  
46 capacities represent the gateway to other executive and memory functions, the latter allowing us  
47 to adapt to the demands of daily life (Nobre et al., 2014; Cohen, 2011). According to the  
48 preceding definitions, the presence of inattention would cause a deleterious effect on overall  
49 cognitive performance due to the processing of information irrelevant to the accomplishment of  
50 a task, at the expense of relevant information (Baldwin, 2012). Therefore, with a growing body of  
51 research showing that the presence of background music influences cognitive functioning (for  
52 review, see Kämpfe et al., 2010), it is important to better understand the influence of background  
53 music on selective attention. Particularly, this would allow for the development of  
54 recommendations aiming to optimize efficient performance in everyday life.

55 Research investigating the effects of background music on selective attention performance has  
56 shown mixed results; sometimes showing neutral (Cloutier et al., 2020; Deng & Wu, 2020;  
57 Speer, 2011; Petrucelli, 1987; Cassidy & Macdonald, 2007; Wallace, 2010), beneficial  
58 (Amezcuca et al., 2005; Darrow et al., 2006; Masataka & Perlovsky, 2013; Slevc et al., 2013;  
59 Cassidy & Macdonald, 2007; Fernandez et al., 2019), or deleterious (Deng & Wu, 2020;  
60 Masataka & Perlovsky, 2013; Slevc et al., 2013; Cloutier et al., 2020; Fernandez et al., 2019)  
61 effects on performance. However, multiple factors can influence this variability, such as the  
62 methodological limits observed within this literature. Several studies present small samples of  
63 adult participants, making it difficult to generalize the results to the general adult population ( $\leq$

64 24 adult participants; Fernandez et al., 2019; Speer, 2011; Amezcua et al., 2005; Cloutier et al.,  
65 2020; Giannouli, 2012). In addition, most of the time, non-auditory (e.g., silence) and auditory  
66 (e.g., noises with sound characteristics similar to those of music) control conditions were lacking  
67 (Darrow, 2006; Marchegiani & Fafoutis; 2019; Deng & Wu, 2020; Cloutier et al., 2020). There  
68 were also methodological limitations regarding the choice of the sound material used. For  
69 example, some studies have presented music with words (e.g., Darrow et al., 2006; Speer, 2011;  
70 Marchegiani & Fafoutis, 2019; Deng & Wu, 2020), which has generally resulted in a deleterious  
71 effect on performance. However, several studies have previously shown that the presence of  
72 speech or words in a sound environment tends to negatively affect cognitive performance in  
73 comparison with a speechless sound environment (e.g., Salamé & Baddeley, 1989; Szalma &  
74 Hancock, 2011). Therefore, the effect of language processing is confounded with the effect of  
75 background music in these studies.

76 Another element that could explain the variability between the results of previous studies is the  
77 lack of control over the emotional characteristics of the sound stimuli being utilized [as discussed  
78 in Schellenberg & Weiss (2013) and Kämpfe et al. (2011)]. Indeed, different sound environments  
79 can induce different emotions. Particularly for musical stimuli, musical parameters, such as  
80 tempo, can be modulated to induce different musical emotions, like the level of arousal  
81 (Gabrielsson & Juslin, 2003); music with fast tempi are usually considered as stimulating, while  
82 music with slow tempi are considered as relaxing (Bigand et al., 2005; Vieillard et al., 2008;  
83 Västjäll, 2001). The emotional characteristics of a sound stimuli, like its level of arousal, are  
84 important to consider as studies have shown links between them and performance on cognitive  
85 tasks (e.g., spatial skills, Thompson et al., 2001; selective attention, Ghimire et al., 2019).  
86 Indeed, according to the arousal-mood hypothesis (Husain et al., 2002; Nantais & Schellenberg,

87 1999; Schellenberg & Hallam, 2005; Schellenberg et al., 2008; Thompson et al., 2001;  
88 Thompson et al., 2011), cognitive performance can be promoted by sound stimulation, notably  
89 by increasing physiological activation and improving mood. Both music and noise can induce  
90 emotions (Hunter & Schellenberg, 2010), but there is a general agreement that music is efficient  
91 to induce positive emotions, and therefore it can be employed to positively modulate mood  
92 (Thompson et al., 2001). The previously cited research by Husain, Thompson, Schellenberg and  
93 their colleagues has shown that when participants listen to music that positively alters their mood  
94 before performing a cognitive task, like a stimulating and pleasant music, their performance in  
95 this cognitive task was improved (Schellenberg & Weiss, 2013). The arousal-mood hypothesis  
96 has been built on data that are based on listening to a stimulus before the accomplishment of a  
97 cognitive task.

98 The objective of this current study was to investigate the effect of the arousal level of  
99 background music on adults' selective attention. To do so, we compared the effect of stimulating  
100 and relaxing music on performance at a Stroop-type task, with two music-matched noise  
101 conditions (stimulating music-matched-noise and relaxing music-matched noise), and a silence  
102 condition.. Based on the arousal-mood hypothesis, we hypothesized that the sound environment  
103 judged to be the most stimulating and pleasant - the stimulating music condition - would be the  
104 most beneficial environment to optimize cognitive performance.

105

## 106 **MATERIALS AND METHODS**

### 107 **Participants**

108 46 participants [27 females (58.7% of the sample), mean age: 25.57 years  $\pm$  4.33, mean years of  
109 education: 17.1 years  $\pm$  2.24]. All participants were native French speakers, had normal hearing  
110 (measured by a brief hearing test done with an audiometer AC40 Interacoustics; participants had  
111 pure tone thresholds under 40 dB SPL; World Health Organization, 1980) and normal or  
112 corrected-to-normal vision. None of the participants had colour blindness or a history of  
113 neurological/psychiatric/neurodevelopmental disorders. None of them were taking drugs or  
114 medication that affected the central nervous system during the study. In addition, participants  
115 were excluded if they presented at least one of the following criteria: (i) music perception  
116 deficits (i.e., performance below 73% at the scale subtest, 70% at the off-beat subtest, and 68%  
117 at the out-of-key subtest of the online Montreal Battery of Evaluation of Amusia (MBEA; Peretz  
118 & Vuvan, 2017); (ii) presence of mood disorders, evaluated with the Beck Depression Inventory-  
119 II (BDI-II; Beck et al., 1996) and the Beck Anxiety Inventory (BAI; Beck et al., 1988) and (iii)  
120 musicians. Individuals were considered musicians if they completed equal to or more than five  
121 years of formal music lessons or were self-taught under that time frame in learning/practicing an  
122 instrument, and were practicing a musical instrument equal to or more than two hours per week  
123 (Zhang et al., 2020). The average number of years of musical training/practice of the participants  
124 (calculated by taking the number of years of formal music training added to the number of years  
125 of autodidactic learning or practicing an instrument) was 1.95 years  $\pm$  2. All participants gave  
126 their written informed consent in accordance with regulation of the local ethics committee at the  
127 University of Montreal.

### 128 **Auditory materials**

129 The 16 auditory stimuli encompassed eight musical excerpts and eight acoustically music-  
130 matched noise stimuli. The eight musical stimuli (four highly pleasant and stimulating excerpts

131 and four highly pleasant and relaxing excerpts) were selected from our lab database of 42 short  
132 instrumental classical music excerpts, all in major mode. The selection was made based on  
133 valence (i.e. 0 = very unpleasant – 100 = very pleasant), arousal (i.e. 0 = very relaxing – 100 =  
134 very stimulating) and familiarity judgments (i.e. 0 = unknown – 100 = very familiar) obtained by  
135 46 non-musicians who did not participate in the current study; using visual analogue scales  
136 (Nadon et al., 2016; for more information see **Supplementary material**). The original excerpts  
137 from our database consisted of the first 30 sec of each piece of music. In order to be able to  
138 accumulate enough data for each musical excerpt during the experimental task, the excerpts for  
139 the current study were made up of the first 60 sec of the same musical pieces. Using data from  
140 Nadon et al. (2016), independent-samples t-tests revealed that excerpts in the relaxing condition  
141 differ significantly from the ones in the stimulating condition in terms of arousal (respectively,  
142  $M = 11.73 \pm 11.1$ ,  $M = 79.18 \pm 18.75$ ;  $t_{(366)} = -42$ ,  $p < .001$ ,  $\eta^2 = .82$ ) and familiarity  
143 (respectively,  $M = 44.35 \pm 36.72$ ,  $M = 91.35 \pm 19.25$ ;  $t_{(366)} = -15.38$ ,  $p < .001$ ,  $\eta^2 = .39$ ). No  
144 difference of valence was found between the relaxing and stimulating excerpts (respectively,  $M$   
145  $= 80.61 \pm 18.72$ ,  $M = 78.43 \pm 21.11$ ;  $t_{(366)} = -1.1$ ,  $p = .3$ ,  $\eta^2 = .01$  (see **Supplementary material**  
146 for more information).

147 For auditory control conditions, acoustically music-matched noises were created based on the  
148 signal-processing procedure used in previous research (Blood et al., 1999; Zatorre et al., 1994).  
149 The spectral envelope of each music stimulus was exported and applied to a synthesized white  
150 noise. This generated “noise melody” was thus different for each matched music stimuli. To  
151 ensure that participants would not recognize the rhythmic patterns from the matched music piece  
152 while listening to the music-matched noise stimulus, each noise stimulus was played in reverse  
153 to create the final music-matched noise stimulus.



154 The final 16 stimuli (i.e., eight musical excerpts and eight acoustically music-matched noise  
155 excerpts) were normalized in amplitude, had a duration of 60 sec, with 1 sec ms fade-in and 2  
156 secfade-out. All above sound processing was performed using Adobe Audition 3.0 software  
157 (Adobe Systems Inc., San Jose, CA, USA).

### 158 **Experimental Stroop Task**

159 Participants performed the task in a soundproof room. Visual information was displayed on a  
160 computer monitor at a distance of 60 cm, while auditory information was presented binaurally  
161 using headphones (DT770 Pro, Beyerdynamic) at a sound level ranging approximately around 60  
162 decibels. This decision was made based on the results of Thompson et al. (2011) in which music  
163 demonstrated a deleterious effect on reading comprehension performance when presented at  
164 around 72 decibels, mainly for fast tempo music, compared to when presented at 60 decibels.  
165 Based on these results, 60 decibels appears to be the ideal sound level to perform a cognitive task  
166 simultaneously . Participants had access to a keyboard and a mouse, all of which were connected  
167 to the computer (HP ProDesk 600 G1, Windows 7) located outside the room, on which the task  
168 was run. Communication between inside and outside the soundproof room was done using  
169 microphones.

170 Selective attention was measured using a computerized Stroop-type task (Stroop, 1935;  
171 customized scripted and inspired by the Double trouble task from the *Cambridge Brain Sciences*  
172 *team*<sup>1</sup>). Each trial presented a target word (RED or GREEN) that appeared above two response  
173 words (RED and GREEN, see **Figure 1**). The color of the target word was either congruent (e.g.,

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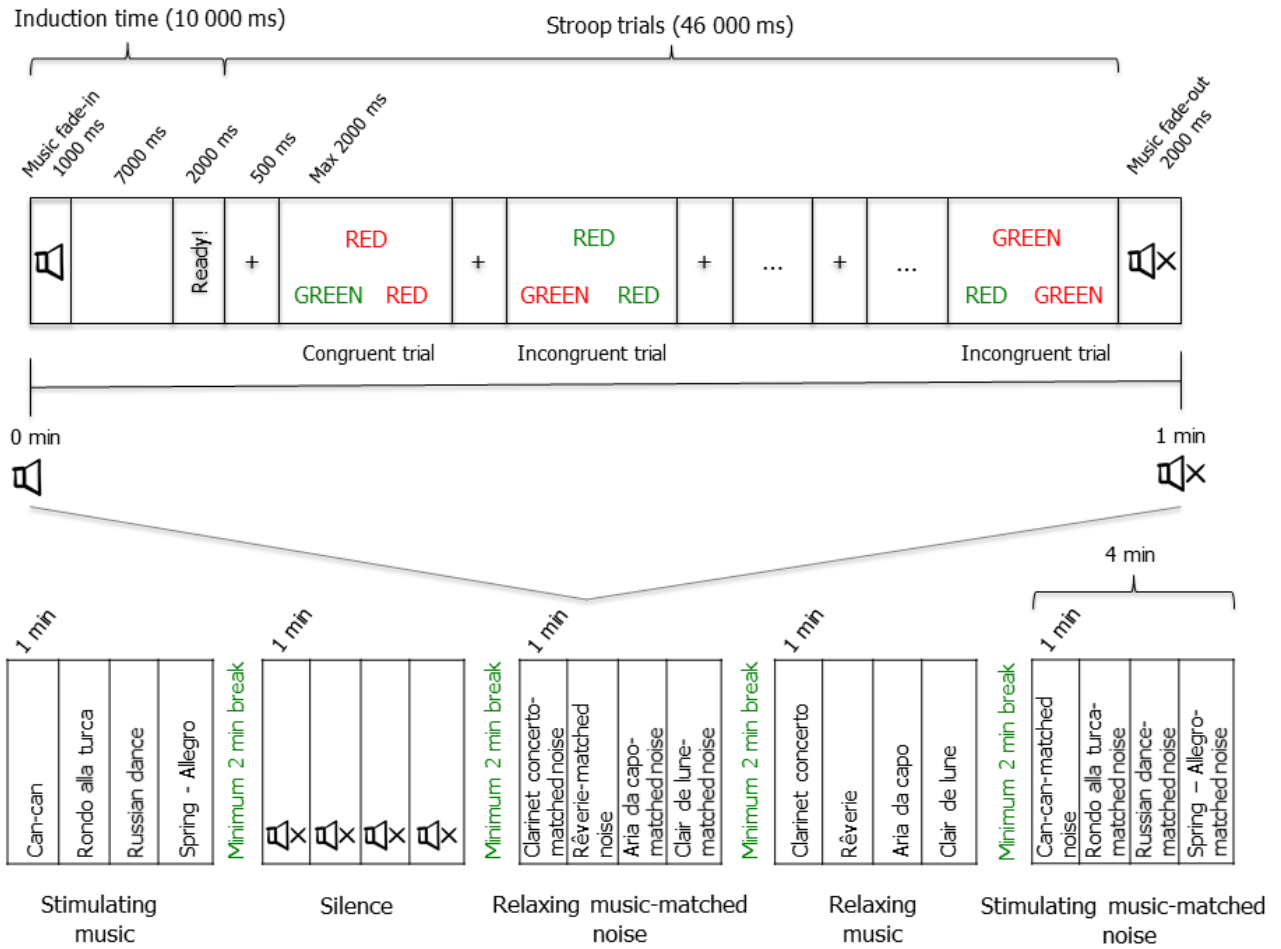
<sup>1</sup> See: [www.cambridgebrainsciences.com/tests/double-trouble](http://www.cambridgebrainsciences.com/tests/double-trouble)

174 the word **RED** presented in red ink) or incongruent (e.g., the word **RED** presented in green ink)  
175 to the meaning of the word. To add a level of difficulty, when the trial was incongruent, the ink  
176 color in which the response words were presented was also incongruent. Participants therefore  
177 had to identify the ink color of the target word by selecting (with the keyboard arrows left and  
178 right) the correct response word presented underneath. The presentation of stimuli, and the  
179 recording of the type of stimuli presented, response time and accuracy, were carried out using the  
180 Psychtoolbox-3.0.13 (developed by Matlab and GNU Octave) implemented in Matlab 2015b  
181 (Mathworks Inc., Natick, MA, USA).

182 Participants were instructed to perform Stroop trials while being as fast and accurate as possible.  
183 Each Stroop trial consisted of a fixation cross (presented 500 ms, see **Figure 1**) followed by one  
184 of the eight possible color-word stimulus options, presented in a pseudo-randomized order.  
185 Participants had a maximum of 2 000 ms to give their answer. If participants answered before  
186 this given time, another trial began and so on. Past this time, the trial ended, a missed trial was  
187 recorded, the words “Too late” appeared on the screen (for 400 ms), and the next trial began.

188 **Figure 1**

189 *Schematic representation of the experimental procedure and experimental Stroop block*



190

191 **Procedure**

192 Participants practiced performing the task in three blocks of 30 sec, with a possibility to take a  
 193 break between the blocks in order to clarify instructions if needed. Each block was performed  
 194 respectively in silence; accompanied by a music stimulus previously judged to have a neutral  
 195 level of activation and high level of valence (see **Table S1**; Nadon et al., 2016), and with the  
 196 matched noise stimulus. Practice blocks were similar to experimental blocks, except that the  
 197 participants responded to Stroop trials for only 16 sec. During these practice blocks, participants  
 198 received feedback for their answers (correct/incorrect; for 800 ms). After completing the three

199 practice blocks, participants could choose to receive the instructions specific to the experimental  
200 part, or to continue practicing (by performing all three blocks again).

201 For the experimental testing, participants performed the Stroop task in five sound conditions:  
202 Silence (S), relaxing music (RM), relaxing music-matched noise (RMN), stimulating music  
203 (SM), and stimulating music-matched noise (SMN; see **Figure 1**). The order in which  
204 participants performed the sound conditions was counterbalanced across participants and the  
205 order of presentation of musical or noise stimuli inside the same sound condition was  
206 randomized across participants using the Matlab script. Each sound condition consists of four  
207 consecutive blocks of 60 000 ms. Each block began with an induction phase (for 8 000 ms)  
208 presenting a blank screen while the participant either listened to the music or noise played, or  
209 remained in silence, depending on the sound condition that was performed (see **Figure 1**). Then,  
210 the word “Ready!” was presented (for 2 000 ms), followed by the beginning of a 46 000 ms  
211 sequence of Stroop task trials. Participants therefore performed their last Stroop trial just before  
212 the sound fade-out, when applicable. When participants completed a sound condition (total of  
213 four minutes), they had to take a break of at least two minutes, during which they left the  
214 soundproof room to fill out the questionnaires, until they were asked to return to the room to  
215 perform the next condition.

216 After completing the task, participants were asked to listen to each auditory stimulus they heard  
217 during the task. Stimuli were presented in a randomized order and visual analog scales were  
218 showed on the screen. Participants were asked to evaluate the level of arousal [very relaxing (0)  
219 to very stimulating (100)], valence [very unpleasant (0) to very pleasant (100)], and familiarity  
220 [unknown (0) to very familiar (100)] for each auditory stimulus.

221 **Data analyses**

222 Accuracy (error rate (ER); percentage of incorrect responses excluding missed trials) and mean  
223 response times (RT) of correct responses trials were computed for each participant, for each  
224 sound condition (i.e., RM, NRM, SM, NSM and S) and Stroop congruence trial type (i.e.,  
225 congruent and incongruent). A trial was considered correct when the participant was able to  
226 accurately identify the ink colour of the target word within the imposed time limit (2 000 ms). Of  
227 these correct trials, a first mean and standard deviation were calculated, and only RT between -  
228 1.97 and 1.97 standard deviation from the participant's mean were used to calculate mean RT.  
229 The Stroop interference effect was calculated by subtracting mean RT of congruent from  
230 incongruent conditions (i.e., mean RT incong. – mean RT cong.) for each sound condition. Mean  
231 ER and RT were entered into separate repeated measures analyses of variance (ANOVAs) with  
232 Sound Conditions and Stroop Congruence trial type as within-subject factors. Mean Stroop  
233 interference scores were entered into another repeated measures ANOVA with Sound Conditions  
234 as within-subject factor. When interactions or a principal effect were significant, t-test analysis  
235 were performed.

236 Paired-sample t-tests were performed to evaluate differences between judgments of arousal,  
237 valence and familiarity for the musical stimuli and the music-matched noise stimuli (see **Table**  
238 **S2**). All data were analyzed using IBM SPSS Statistics 26 (IBM Corp., 2019). The alpha levels  
239 were set at .05 for all analyses.

240 **RESULTS**

241 **Auditory stimuli evaluation**

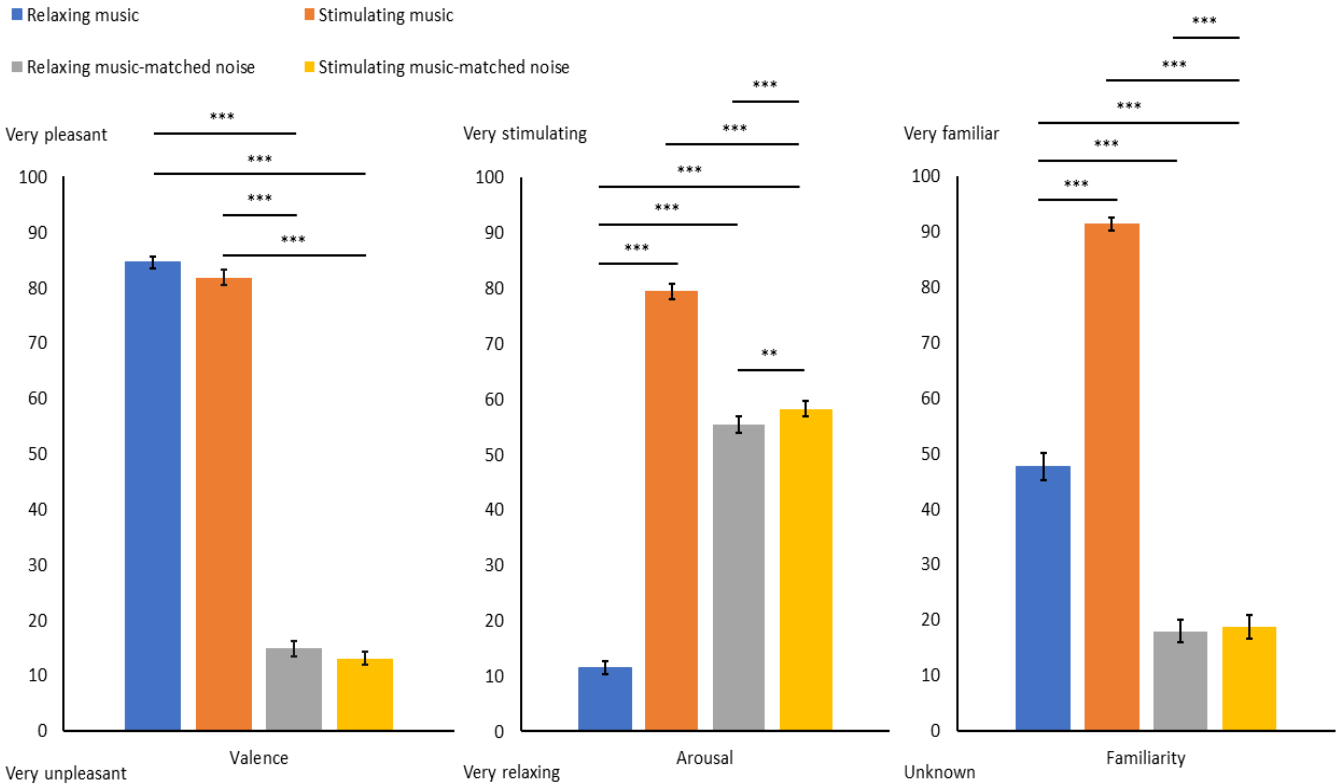
242 As expected, judgments of arousal from participants were significantly higher for the stimulating  
243 music (SM) compared to the relaxing music (RM). The arousal was judged significantly higher  
244 for the two noise conditions (RMN and SMN) compared to the RM. Similarly, the arousal was  
245 judged significantly lower for the two noise conditions (RMN and SMN) than for the SM. SMN  
246 was considered significantly more stimulating than RMN (see **Figure 2** and **Table S3** for details  
247 on arousal's results).

248 For the evaluation of valence, as expected, participants considered that the two music conditions  
249 (RM and SM) were significantly more pleasant than the two noise conditions (RMN and SMN).  
250 There was no significant difference between the two music conditions (RM and SM) and the two  
251 noise conditions (RMN and SMN) in terms of valence (see **Figure 2** and **Table S3** for details on  
252 valence's results).

253 The most familiar condition was SM, followed by the RM condition, with the other two noise  
254 conditions being significantly less familiar (RMN and SMN). There was no difference between  
255 the level of familiarity among the two noise conditions (RMN and SMN; see **Figure 2** and **Table**  
256 **S3** for more details).

257 **Figure 2**

258 *Mean scores for the emotional judgments of valence and arousal and mean scores for the*  
259 *evaluation of familiarity for each sound condition*



260 Notes. Graph shows standard errors.  
261

262 \*\* $p < .01$ .

263 \*\*\* $p < .001$

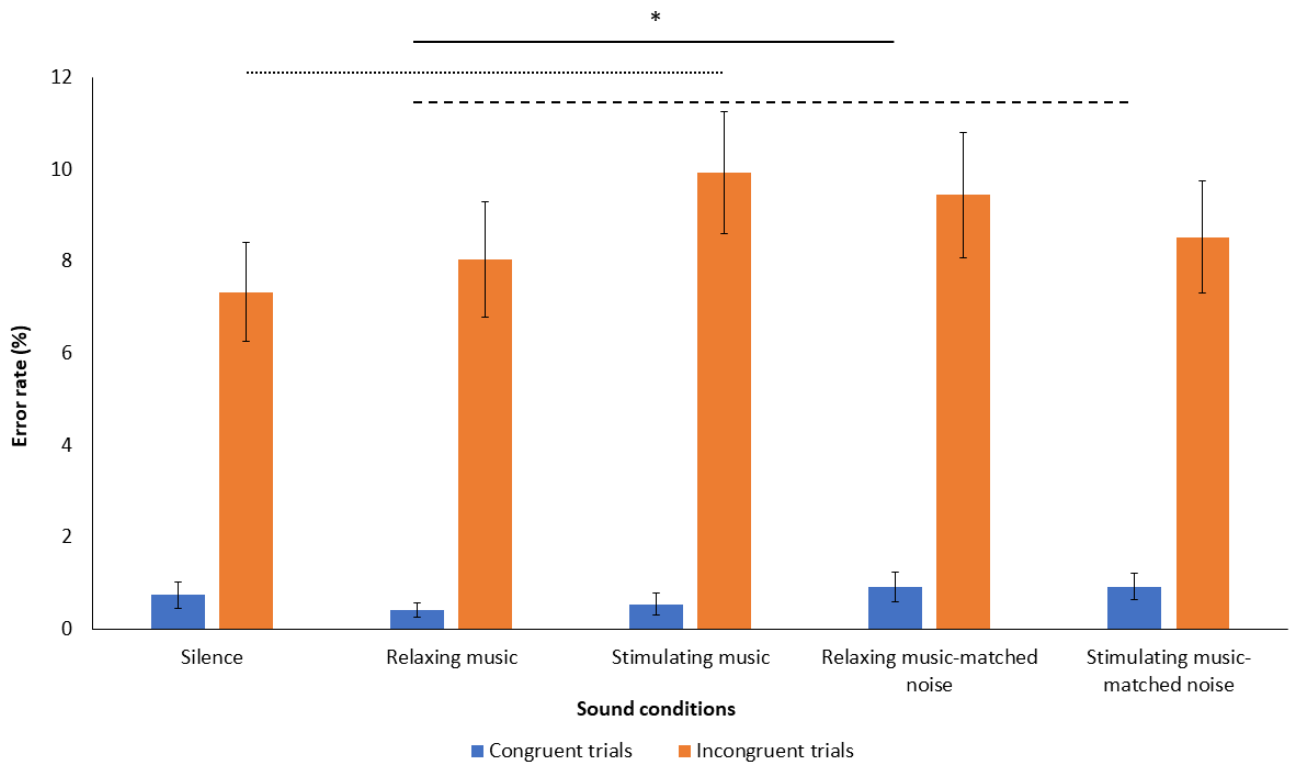
264 **Stroop task**

265 The correct response time (RT) and error rate (ER) analyzes supported the observation of a  
 266 Stroop interference effect as RTs were significantly slower and ERs were higher on incongruent  
 267 trials compared to congruent trials (effect of congruence on RTs:  $F_{(1, 45)} = 253.93, p < .005, \eta^2 =$   
 268  $.85$ ; effect of congruence on error rate:  $F_{(1, 45)} = 104.158, p < .005, \eta^2 = .70$ ). In terms of RT on  
 269 incongruent and congruent trials, there were no significant differences in performance between  
 270 the different sound conditions ( $F_{(1, 45)} = 1.01, p = .405, \eta^2 = .02$ ). In the analysis of ERs for  
 271 incongruent and congruent trials in each sound condition, the ER for congruent trials in the RMN  
 272 condition was significantly higher than in the RM condition ( $t_{(45)} = 2.10, p < .05, \eta^2 = .09$ ). A

273 similar tendency is noted between the ER for congruent trials in the SMN condition compared to  
 274 the ER in RM condition ( $t_{(45)} = 1.81, p = .077, \eta^2 = .07$ ). Regarding the ER for incongruent trials,  
 275 there was a trend towards a higher ER in the SM condition compared to the silence condition  
 276 ( $t_{(45)} = -1.69, p = .097, \eta^2 = .06$ , see **Figure 3** and **Table S4** for more details on Stroop’s task  
 277 results). No significant effect was found in the analysis with the mean Stroop interference effect  
 278 scores for each sound condition ( $F_{(1, 45)} = 0.394, p = .813, \eta^2 = .009$ ).

279 **Figure 3**

280 *Mean error rate on incongruent and congruent trials for each sound condition*



281

282 *Notes. Graph shows standard errors.*

283 \* $p < .05$ .

284 - - - - =  $p = .07$ .



285 ..... = p = .09.

286 **DISCUSSION**

287 The aim of this study was to investigate the effect of the arousal level of background music on  
288 selective attention of adults. The results there did not reveal any significant differences in  
289 attentional performance depending on whether the task was performed in silence, accompanied  
290 by relaxing music or stimulating music. Even though the results showed that participants tended  
291 to make a greater number of errors when listening to stimulating music compared to silence, this  
292 difference was not significant. However, when comparing on-task performance in the presence  
293 of music or noise, performance is more affected by the presence of noise given that there is a  
294 significant difference in error rate for congruent trials between relaxing music (RM) and relaxing  
295 music-matched noise (RMN), and a trend between relaxing music and relaxing music- matched  
296 noise (SMN).

297 These results are somewhat encouraging as they showed that the addition of to-be processed  
298 cognitive information (e.g., background music/noise) does not necessarily have deleterious  
299 effects on attentional performance as some theories suggests (e.g., Kahneman's (1973) limited  
300 capacity model). With these results, it is possible to assume that performing a task requiring  
301 attention in the presence of instrumental music should not have a negative effect on the level of  
302 selective attention demand in order to perform the task optimally.

303 The arousal-mood hypothesis (Husain et al., 2002; Nantais & Schellenberg, 1999; Schellenberg  
304 & Hallam, 2005; Schellenberg et al., 2008; Thompson et al., 2001; Thompson et al., 2011)  
305 suggests that a sound environment judged to be stimulating and pleasant would be a beneficial  
306 environment to optimize cognitive performance (for details, see Schellenberg & Weiss, 2013). It  
307 was therefore expected that the stimulating music condition would be the sound environment in

308 which we would see the lowest error rate and weakest Stroop interference. In contrast to the  
309 hypotheses, the presence of pleasant and stimulating music during the accomplishment of the  
310 task did not significantly improve task performance. A small tendency to make more errors on  
311 incongruent trials in this sound environment was also noted. These results differ from those of  
312 previous work studying the effect of the arousal level of background music upon selective  
313 attention (Cloutier et al., 2020; Fernandez et al., 2019). However, these studies mainly aimed to  
314 make comparisons between groups (elderly vs young adults), while the present study had an  
315 objective of generalization to the adult population. Furthermore, the tasks involved were  
316 different: while previous studies employed the Flanker task to assess selective visual attention,  
317 the current study utilized the Stroop task which involves language processing. On the other hand,  
318 the number of sound conditions in this study may affect the statistical power of the results. It  
319 would therefore be interesting to investigate whether the results would be the same with even a  
320 larger sample-size in future studies (even though our sample-size was larger than in previous  
321 studies).

322 A key finding of this study is a negative effect of music-matched noise stimuli (low  
323 pleasantness) on attentional performance. These results converge with previous work by  
324 Masataka & Perlovsky (2013) and Slevc (2013) showing lower performance on a similar Stroop  
325 task in the presence of dissonant music (sound pairings perceived as generally unpleasant or  
326 possessing low-pleasantness valence). Interestingly in these studies, greater consonance (sound  
327 pairings perceived as generally pleasant or possessing a high-pleasantness valence) led to better  
328 performance on the Stroop task. It would therefore be interesting to investigate further to assess  
329 which factor, the level of valence/pleasantness or the degree of consonance, had the greater  
330 influence upon the results of this and previous studies (Masataka & Perlovsky 2013 and Slevc,

2013). This could be done by integrating stimuli that are both consonant and unpleasant, such as scary or sad music, or by specially composed music material. In previous research, the relationship between background music and cognitive performance seems to be affected by the degree of familiarity of the musical stimulus (if the music was already known to the participant). Higher familiarity has a positive effect on performance for cognitive tasks (Darrow et al., 2006; Speer, 2011; Giannouli, 2012). One potential limitation of this study is that, despite an attempt to select equally familiar music of similar valence, the stimulating musical stimuli were rated as more familiar by the participants than the relaxing musical stimuli (see **Supplementary materials** for details). It is then surprising that the present findings did not support an effect of stimulating music on task performance given that the stimulating music condition was biased towards higher familiarity.

Judgments of valence can be influenced by the familiarity of a musical piece. Some studies have shown that perceivers tend to find a stimulus that they already know (e.g., a piece of music) more pleasant (Parente, 1976; Van Den Bosch et al., 2013; Schellenberg et al., 2008). Familiar background music has also been associated with increased pleasure in the process of completing a task without compromising task performance (Feng & Bidelman, 2015; Pereira et al., 2011). In this regard, Kiss and Linnell (2020), Darrow and colleagues (2006), Speer (2011), and Giannouli (2012) asked their participants to bring their favourite music into the lab, which then was used as background music to perform a selective attention task or a sustained-attention task. In these studies, the music selected by the participants held characteristics of high emotional valence and familiarity. However, the other characteristics of the music utilized were heterogeneous between participants (e.g., style, complexity of the music pieces, presence of lyrics, or the level of arousal). The results of these studies indicate that participants consistently performed better in

354 the familiar music conditions. As we know little about the characteristics of the different pieces  
355 of music used in these studies and that a great variability is present between them, it is difficult  
356 to identify whether the results are generalizable to listening to background music in general or  
357 whether they are specifically attributable to a modulation of mood and/or arousal due to the  
358 emotional characteristics and familiarity of the music used. Future research should combine this  
359 approach with systematic acoustic as well as musical and linguistic structure analyses of the used  
360 material to further our understanding of the potential characteristics involved in the observed  
361 effects.

362 Taken together, our findings suggest that it is not sufficient for background music to be arousing,  
363 pleasant and familiar in order to enhance attentional performance as suggested by the Arousal-  
364 mood theory, and that factors related to individual musical taste may be driving the effects found  
365 in previous studies.

366 Finally, based on the results of this study, we can therefore recommend that tasks requiring  
367 selective attention can be performed in an environment of silence as well as with pleasant  
368 instrumental music. Findings from this study can be extended to practical use in environments  
369 with loud or unpleasant intermittent noises (for example open-plan offices or when space for  
370 telework must be shared). According to Szalma & Hancock (2011), intermittent unpredictable  
371 short noise bursts are the most disturbing forms of noise; these could be the sound of a horn  
372 outside, the laughter of a colleague in a nearby open-plan office, a family member shutting a  
373 door nearby, etc. Listening to music in the background may be an efficient tool, equal to working  
374 in silence, for masking unpleasant intermittent noises while maintaining a similar level of  
375 selective attention on a given task. In this light, future work comparing the presence of music  
376 with pleasant noises (such as waves or waterfall noises) would be interesting to investigate given  
377 their potential for masking intermittent noises.

378 **DATA AVAILABILITY STATEMENT**

379 The raw data supporting the conclusions of this article will be made available by the authors,  
380 upon reasonable request.

381 **ETHICS STATEMENT**

382 The studies were reviewed and approved by the Comité d'éthique de la recherche en arts et en  
383 sciences (CÉRAS), University of Montreal, Montreal, Canada. Written informed consent to  
384 participate in this study was provided by the participants.

385 **AUTHOR CONTRIBUTIONS**

386 EN, BT and NG contributed equally to the project's conception and the study design. EN  
387 performed the literature search and EN and AS drafted the manuscript. EN and AS performed the  
388 statistical analysis. BT, NG and EN contributed to the establishment of the Stroop task  
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390 and approved the submitted version.

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400 **CONFLICT OF INTEREST**

401 The authors declare that the research was conducted in the absence of any commercial or  
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557

## 558 SUPPLEMENTARY MATERIAL

## 559 Table S1

560 *Description of musical stimuli*

Piece title	Results from the emotional judgment of 46 non-musicians (Nadon et al., 2016)			Descriptive information of each stimulus	
	Arousal <sup>a</sup>	Valence <sup>b</sup>	Familiarity <sup>c</sup>	Tempo (bpm) <sup>d</sup>	Interpret
Neutral music for the practice part					
Cello Suite No. 1 in G Major (BWV 1007): 1. Prélude/Bach	51.45 (24.1)	83.88 (22.78)	87.72 (17.58)	135	István Várdai
Relaxing music					
Clarinet concerto in A major (K622) – 2. Adagio/Mozart	13.28 (12.2)	78.86 (20.62)	51.52 (31.68)	80	Anthony Pike, English Chamber Orchestra & Ralf Gothóni
Rêverie/Debussy	13.77 (11.7)	78.34 (18.81)	35.14 (34.26)	65	Rebecca Arons
Goldberg variations (BWV988) – Aria Da Capo/Bach	10.35 (10.35)	81.26 (17.88)	33.21 (34.07)	75	Nicola Frisardi
Suite bergamasque – 3. Clair de lune/Debussy	9.5 (9.65)	84 (17.51)	57.54 (41.24)	70	François-Joël Thiollier
Stimulating music					
Can-can from Orpheus in the Underworld/Offenbach	82.27 (14.52)	76.21 (22.71)	89.37 (20.7)	160	Charles Gerhardt & London philharmonic orchestra
Piano Sonata No.11 in A Major (K331) – Rondo: alla turca/Mozart	73.33 (23.86)	84.72 (15.53)	94.92 (14.71)	110	Finghin Collins
Russian dance from The Nutcracker/Tchaikovsky	88.66 (12.42)	78.01 (19.99)	86.38 (24.27)	140	Heinz Rögner & Berlin Radio Symphony Orchestra

Concerto No. 1 in E major, Op. 8	72.45	74.78	94.74	115	Jonathan Carney & Royal
(RV 269) – Spring 1. Allegro/Vivaldi	(17.66)	(24.44)	(14.81)		Philharmonic Orchestra

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561 *Note.* This table presents means (and standard deviations) for emotional judgment of arousal, valence and familiarity compiled  
 562 with a computerized version of visual analog scales. The table shows the data from the previous research by Nadon et al. (2016).

563 <sup>a</sup> 0 = very relaxant, 100 = very stimulating

564 <sup>b</sup> 0 = very unpleasant, 100 = very pleasant

565 <sup>c</sup> 0 = unknown, 100 = very familiar

566 <sup>d</sup> bpm = beat per minute

567

568



569 **Table S2**570 *Participant judgment of auditory stimuli*

Stimuli title	Results from the emotional judgment of 46 non-musicians (Nadon et al., 2016)			Results from the emotional judgment of 46 non-musicians from this study		
	Arousal <sup>a</sup>	Valence <sup>b</sup>	Familiarity <sup>c</sup>	Arousal <sup>a</sup>	Valence <sup>b</sup>	Familiarity <sup>c</sup>
<b>Relaxing music and their matched noise condition</b>						
Clarinet concerto in A major (K622) – 2.	13.28	78.86	51.52	17.44	85.32	60.28
Adagio	(12.2)	(20.62)	(31.68)	(18.12)	(12.68)	(31.32)
Clarinet concerto-matched noise				56.47	15.08	17.88
				(21.21)	(19.33)	(29.03)
Mean comparison between music and music-matched noise				-9.59***	20.64***	8.79***
Rêverie	13.77	78.34	35.14	12.91	82.96	33.28
	(11.7)	(18.81)	(34.26)	(18.05)	(14.95)	(25.12)
Rêverie-matched noise				57.84	11.03	19.90
				(21.09)	(15.34)	(28.26)
Mean comparison between music and music-matched noise				22.95***	-10.67***	2.6*
Goldberg variations (BWV988) – Aria	10.35	81.26	33.21	9.83	81.89	30.62
Da Capo	(10.35)	(17.88)	(34.07)	(13.17)	(15.79)	(27.42)
Aria da capo-matched noise				54.42	19.29	16.89
				(20.36)	(22.06)	(27.16)
Mean comparison between music and music-matched noise				-12.57***	17.84***	2.56*
Suite bergamasque – 3. Clair de lune	9.5	84	57.54	6.16	88.00	66.49

## Effect of music on attention

	(9.65)	(17.51)	(41.24)	(9.16)	(15.24)	(33.36)
Clair de lune-matched noise				52.89	14.05	17.04
				(21.61)	(18.27)	(28.54)
Mean comparison between music and music-matched noise				-13.38***	20.32***	8.98***
Stimulating music and their matched noise condition						
Can-can from Orpheus in the Underworld	82.27	76.21	89.37	81.67	77.54	84.01
	(14.52)	(22.71)	(20.7)	(15.37)	(19.49)	(22.13)
Can-Can-matched noise				56.28	15.03	17.95
				(19.36)	(16.38)	(28.85)
Mean comparison between music and music-matched noise				7.9***	16.87***	14.45***
Piano Sonata No.11 in A Major (K331) – Rondo: alla turca	73.33	84.72	94.92	75.73	83.78	95.98
	(23.86)	(15.53)	(14.71)	(22.01)	(20.49)	(7.67)
Rondo: alla turca-matched noise				60.70	11.95	17.64
				(18.02)	(15.16)	(27.92)
Mean comparison between music and music-matched noise				3.02**	18.0***	19.19***
Russian dance from The Nutcracker	88.66	78.01	86.38	84.99	83.47	89.36
	(12.42)	(19.99)	(24.27)	(16.24)	(19.74)	(18.89)
Russian dance-matched noise				57.97	13.64	22.40
				(18.19)	(16.59)	(31.62)
Mean comparison between music and music-matched noise				8.22***	17.49***	14.65***
Concerto No. 1 in E major, Op. 8 (RV 269) – Spring 1. Allegro	72.45	74.78	94.74	75.28	82.37	96.05
	(17.66)	(24.44)	(14.81)	(20.02)	(18.59)	(6.42)
Spring - Allegro-matched noise				57.92	11.64	16.43
				(20.12)	(14.91)	(27.13)

Mean comparison between music and music-matched noise	4.66***	18.23***	19.7***
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571 *Note.* For the music and music-matched noise rows, this table shows means (and standard deviations) for emotional judgments of  
 572 arousal, valence and familiarity compiled with a computerized version of visual analog scales. The table presents the data from  
 573 previous research by Nadon et al. (2016) and the new data from the current study using the same musical excerpts. For the mean  
 574 comparison between music and music-matched noise rows, paired-samples t-tests were performed to compare mean values for  
 575 emotional judgments of valence, arousal and familiarity for all conditions and scores presented are t-scores.

576 <sup>a</sup> 0 = very relaxant, 100 = very stimulating

577 <sup>b</sup> 0 = very unpleasant, 100 = very pleasant

578 <sup>c</sup> 0 = unknown, 100 = very familiar

579 \**p* < .05. \*\**p* < .01. \*\*\**p* < .001.

580

581 **Table S3**582 *Comparisons between judgments of valence, arousal, and familiarity for each sound condition*

	df	<i>t</i>	<i>p</i>	Effect size ( $\eta^2$ )
Valence				
Relaxing music/Stimulating music	183	1.57	=0.119	=0.01
Relaxing music/Relaxing music-matched noise	183	40.25	=0.000	=0.90
Relaxing music/Stimulating music-matched noise	183	44.33	=0.000	=0.92
Stimulating music/Relaxing music-matched noise	183	31.31	=0.000	=0.84
Stimulating music/Stimulating music-matched noise	183	35.13	=0.000	=0.87
Relaxing music-matched noise /Stimulating music-matched noise	183	1.74	=0.084	=0.02
Arousal				
Relaxing music/Stimulating music	183	-36.89	=0.000	=0.88
Relaxing music/Relaxing music-matched noise	183	-22.46	=0.000	=0.73
Relaxing music/Stimulating music-matched noise	183	-24.78	=0.000	=0.77
Stimulating music/Relaxing music-matched noise	183	11.46	=0.000	=0.42
Stimulating music/Stimulating music-matched noise	183	11.12	=0.000	=0.40
Relaxing music-matched noise /Stimulating music-matched noise	183	-3.01	=0.003	=0.05
Familiarity				
Relaxing music/Stimulating music	183	-16.84	=0.000	=0.61
Relaxing music/Relaxing music-matched noise	183	10.30	=0.000	=0.37
Relaxing music/Stimulating music-matched noise	183	9.77	=0.000	=0.34

## Effect of music on attention

noise				
Stimulating music/Relaxing music-matched	183	34.01	=0.000	=0.86
noise				
Stimulating music/Stimulating music-matched	183	33.11	=0.000	=0.86
noise				
Relaxing music-matched noise /Stimulating	183	-0.75	=0.454	=0.00
music-matched noise				

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583 *Notes.* This table presents the results for paired t-test analysis.

584

585 **Table S4**586 *Means and standard deviations for all study variables by sound condition*

Variables	Sound conditions				
	Silence	Relaxing music	Stimulating music	Relaxing music-matched noise	Stimulating music-matched noise
Congruent Stroop RT (ms)	842.67 (168.67)	839.05 (156.60)	856.64 (120.23)	843.63 (147.86)	836.15 (154.28)
Incongruent Stroop RT (ms)	1093.47 (192.56)	1075.64 (170.17)	1096.68 (168.50)	1083.66 (180.23)	1081.05 (181.72)
Stroop Interference Effect (ms)	251.02 (121.50)	236.43 (123.84)	240.11 (116.00)	239.96 (95.66)	240.11 (123.95)
ER: Congruent Stroop (%) <sup>a</sup>	0.74 (1.87)	0.41 (1.10)	0.54 (1.66)	0.92 (2.21)	0.93 (1.93)
ER: Incongruent Stroop (%) <sup>b</sup>	7.33 (7.33)	8.04 (8.47)	9.92 (8.98)	9.44 (9.20)	8.52 (8.28)
Unsuccessful rate (%) <sup>c</sup>	5.72 (5.62)	6.18 (6.39)	7.00 (6.11)	6.70 (5.84)	6.01 (5.55)

587 *Note.* This table shows mean (and standard deviations) values. Data in the first three rows are in milliseconds (ms) and data in the  
588 last three rows are in percentages; see information below for more details.

589 <sup>a</sup> Error rate: Congruent Stroop: failed trials for congruent trials/total number of congruent trials (failed + successful)

590 <sup>b</sup> Error rate: Incongruent Stroop: failed trials for incongruent trials/total number of incongruent trials (failed + successful)

591 <sup>c</sup> Unsuccessful rate: missed trials + failed trials (wrong answer)/total number of trials (missed + successful + failed)

592