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Efficiency of attentional networks in musicians and non-musicians

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Abstract

Music is a complex and properly human skill. Previous studies indicate that systematic musical training induces specific structural brain changes and improves audio-motor functions. However, whether these benefits can transfer into functional improvements of attentional skills is still little known. To shed light on this issue, in the present study we explored the relationship between long-term musical training and the efficiency of the attentional system. We used the attention network test (ANT) to compare the performance of the alerting, orienting and executive attentional networks of professional pianists against a matched group of non-musician adults. We found musicians were significantly faster to respond across the ANT task, and that the executive attentional network was more efficient in musicians than non-musicians. We found no differences in the efficiency of the alerting and orienting networks between both groups. Interestingly, we found that the efficiency of the executive system improves with the years of musical training, even when controlling for age. We also found that the three attentional networks of the non-musicians were functionally independent. However, in the case of the musicians, the efficiency of the alerting and orienting systems was associated. These findings provide evidence of a potential transfer effect from systematic musical training into inhibitory attentional control.

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1. Introduction

Music is a complex human skill that recruits and integrates different cognitive resources during its practice. Several studies have shown that systematic musical training induces morphological brain changes that correlate with the enhancement of some specific musical abilities (Hyde et al., 2009; Münte et al., 2002; Lappe et al., 2008). For instance, musical training has been linked to changes in the auditory cortex (Bermudez et al., 2009; Gaser & Schlaug, 2003; Schneider et al., 2002), and better performance in tasks involving the recognition of melodies presented in transposition (Halpern et al., 1995), at an unusual tempo (Andrews et al., 1998), to determine how many notes sound simultaneously at a chord (Burton et al., 1989), and to discriminate subtle differences in pitch between two notes (Tervaniemi et al., 2005). Interestingly, musical training not only enhances the detection of some of the fine-grained traits of musical auditory stimuli but also seems to impact on the processing of other complex auditory stimuli. For instance, musical training has been linked to the ability to detect small detuning in spoken sentences (Schön et al., 2004) and to perceive and discern speech within noisy environments (Parbery-Clark et al., 2009). The enhancement of speech perception induced by musical training is a prototypical example of a transfer effect, namely when some skill training (e.g., music) improves performance in some untrained skill (e.g., speech perception). Recently, the transfer effect induced by musical training has drawn the attention of researchers interested in knowing what other extra-musical skills might benefit from a systematic practice of music. So far, studies along this line have been mainly conducted to observe the effects of musical training on executive functions. The most consistent results show signs of transfer of learning on cognitive control (Moreno and Farzan, 2015; Moussard et al., 2016) and working memory (Jakobson et al., 2008; Zuk et al., 2014).

In order to explore other cognitive domains that might benefit from systematic musical training, we focused on the musicians' attentional system, a cognitive mechanism that plays a key role in developing and deploying musical skills and that is strongly tied to executive functions (Diamond, 2013). According to Posner and Petersen (1990; see also Petersen and Posner, 2012), the attentional system consists of three subsystems that are mediated by anatomically distinct neural networks (Fan and Posner, 2004): alerting, orienting, and executive control networks. The alerting function is associated with maintaining states of readiness for action and recruit thalamic and right frontal-parietal regions (Fan et al., 2005). The orienting function is linked to the selection of sensory information and change of attentional focus,

recruiting basal ganglia, parietal areas and frontal eye-fields regions (Corbetta et al., 2008). The executive control function is involved both in the suppression of irrelevant, distracting stimuli and in the top-down attentional control, recruiting the anterior cingulate cortex, lateral and ventromedial prefrontal cortex, orbitofrontal cortex and amygdala (Bush et al., 2000; MacDonald et al., 2000). It is worth to mentioning that although these networks are anatomically independent, the systems can cooperate and work together (Raz and Buhle, 2006), given the presence of contextual or individual variables (Fan et al., 2009). To the best of our knowledge, there have been no studies conducted to date directly inspecting the effects of musical training on these attentional networks. Nevertheless, there are reports linking musical practice with increased performance on selective auditory attention tasks (Strait and Kraus, 2011; Strait et al., 2010; Strait, Slater, O'Connell and Kraus, 2015). The general pattern emerging from these studies highlights a potential link between musical training and the executive characteristics of the attentional system.

The purpose of the present study is to investigate the effects of systematic musical training on the main components of the attentional system, namely, the alerting, orienting, and executive attention networks. To this end, and considering the above outlined body of evidence, we formulate the following hypotheses: (a) the efficiency of the executive attentional network will be greater in musicians than non-musicians; (b) the attentional networks will be more dependent on each other in musicians than non-musicians; (c) the efficiency of the executive attentional system will enhance with years of professional musical training. To test these hypotheses, we recorded the behavioral responses of professional pianists and a matched group of non-musician professional adults engaged in an attentional networks test (ANT) (Fan et al., 2002), consisting of a combination of a cue-target and a flanker task. Briefly, the participants were asked to indicate whether or not a central arrow displayed points in the same direction as the arrows flanking it to the left and right. Visual cues presented before the arrows onset warned the subjects about the task to come or guided the subjects' attention to the place where the arrows appeared later on (Fan and Posner, 2004). According to our hypotheses, we expected that the musicians' attentional networks would be less affected by irrelevant information (congruency effect) than non-musicians, reflecting a better control of the attention and a more efficient behavioral response.

2. Materials and methods

2.1. Participants

Thirty-eight subjects, 19 professional musicians and 19 non-musicians were recruited for a behavioral experiment. Two participants (one musician and one non-

musician) were excluded from further analysis because their mean reaction times (RT) were two standard deviations below or above their group's mean (Ratcliff, 1993). Thus, the final sample consisted of 18 professional musicians (13 male, age range: 17−33 years, mean age = 25.39 years, SD = 3.92) and 18 non-musicians (15 male, age range: 19−33 years, mean age = 26.72 years, SD = 4.61). All of the musicians were piano players. For this study, "Professional musicians" were defined as full-time conservatory students or conservatory graduates with an average of 12.22 years of practice. We recruited the musicians from Conservatories of the Universidad de Chile, Universidad Mayor de Chile, and Universidad Austral de Chile. We defined "Non-musicians" as subjects with university studies that had never received any formal music lessons and could neither play nor read music. They were matched to the musicians group for gender ($\chi2$ (1, N = 36) = .643, p = .423) and age (t(34) = -0.934, p = .357, Cohen's d = 0.310). All participants were native Spanish speakers, right-handed, with normal hearing and normal or corrected to normal vision, with no history of any neurological or psychiatric conditions. The Ethical Committee of the Universidad Metropolitana de Ciencias de la Educación approved the protocols used in this study, and all participants gave written informed consent before being tested.

2.2. Task

The "attention network test" (ANT) (Fan et al., 2002; Posner and Petersen, 1990) was used to assess the efficiency of the networks of musicians and non-musicians. The task consists of indicating the direction of a central arrow (target) flanked by two other arrows (both to the left and the right). The five horizontal black arrows appear on a grey background. The arrows flanking the target pointed either in the same direction as the target stimulus (congruent condition) or in the opposite direction (incongruent condition). A neutral condition was also present, consisting of lines with no arrowheads. The row of arrows could appear above or below a fixation cross in the center of the screen. Participants had to indicate in which direction the target pointed. To assess alertness and orientation, a visual cue (an asterisk) appeared before the arrows were shown. For alertness trials, the asterisk was either not presented (no-cue), or it appeared above and below the fixation cross (double-cue). Trials assessing orientation presented the asterisk in the same position as the fixation cross (center-cue) or either above or below the fixation-cross (spatial-cue), indicating the location of the arrows with 100% accuracy to orient them (Fig. 1).
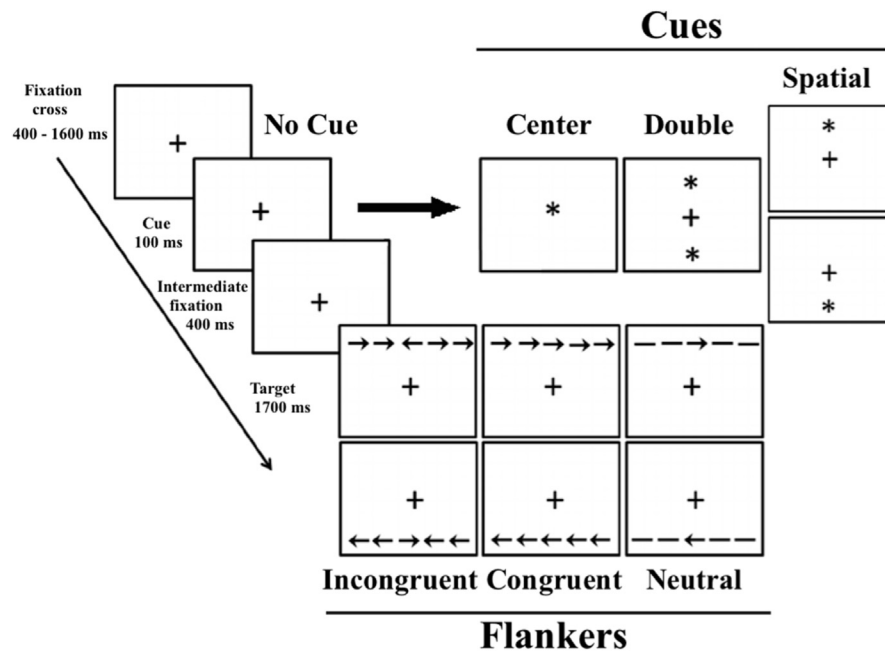
Fig. 1. Attention Network Test (ANT). The four cues conditions (no cue, center, double and spatial) and three flanker conditions (incongruent, congruent and neutral), along with the timeline for each trial, are depicted.

2.3. Procedure

Before the experiment, participants read the instructions on how to perform the attentional task. The experimental session consisted of a block of 24 trials with feedback and three experimental blocks of 96 trials each without feedback. We presented the trials randomly. During the experimental blocks, each trial began with a fixation cross in the center of the screen with a variable duration of $400-1600$ ms; after that, a visual cue appeared (or not), for 100 ms, followed by a brief fixation period of 400 ms. Finally, the row of five arrows was shown for 1700 ms or until the participant answered. After the subject's response, the stimuli disappeared and a variable post-target fixation period appeared, based on the duration of the first fixation period and reaction time (RT) (3500 ms minus duration of the first fixation minus RT) (Fan et al., 2002). At the end of this post-stimulus fixation period, the next trial began. The participants responded by pressing one of two possible buttons to indicate the direction of the central arrow (left or right). We used E-Prime 2.0 (Psychology Software Tools, Inc.) for the presentation of stimuli and the recording of behavioral responses.

2.4. Data analysis and statistics

ANT task analysis. RTs for each participant in all conditions were averaged. To prevent the bias of outliers, trials with incorrect responses or with RTs longer than 1000 ms or shorter than 200 ms were excluded. Kolmogorov-Smirnov test showed that the

RTs followed a normal distribution in both groups (musicians: $D(18) = .138$, $p > .200$; non-musicians: $D(18) = .124$, $p > .200$). The mean RT of correct answers were analyzed by conducting a mixed ANOVA with warning type (orienting cue, double cue, central cue, no cue) and congruency (congruent, neutral, incongruent) as within-subject factors and group (musician, non-musician) as the between-subject factor. The Levene's test indicated that variance was equal across groups (all *p-values* > .127). Post-hoc pairwise comparisons were analyzed via independent or paired two-tailed t-tests as appropriate. The t-tests' effect size was calculated with Cohen's *d*. The significance level was set at 0.05. When necessary we applied a Greenhouse-Geisser correction.

Attentional networks analysis. The efficiency scores of each network were obtained as follows (Fan and Posner, 2004): alerting network = [RT no-cue − RT double-cue], orienting network = [RT center-cue − RT spatial-cue], and executive network = [RT incongruent − RT congruent]. For the alerting and orienting networks, higher scores indicate greater efficiency. Conversely, higher scores in the executive network indicate less efficiency. The networks' score was analyzed by conducting a mixed ANOVA with networks (alerting, orienting, executive) as the within-subject factor and group (musician, non-musician) as the between-subject factor. The Levene's test showed that variance was equal across groups (all *p-values* > .426). Post-hoc pairwise comparisons were analyzed via independent or paired two-tailed t-tests as appropriate. The t-tests' effect size was calculated with Cohen's *d*. The significance level was set at 0.05. When necessary we applied a Greenhouse-Geisser correction.

Correlation analysis. We used Pearson correlation to analyze the association between years of musical training and efficiency of the attentional network, and the independence of attentional systems. We set the alpha level at .05.

3. Results

3.1. Behavioral performance across the ANT task conditions

The results are illustrated in Fig. 2. Percentage of correct answers in the musicians group was 98.18% with an average reaction time of 475.86 ms, whereas in the non-musicians group it was 98.04% with an average reaction time of 513.15 ms. Two tailed independent t-test revealed that average reaction times were significantly different between groups ($t(34) = -2.286$, $p = .029$, Cohen's $d = 0.762$). Difference in accuracy were not found ($t(34) = .186$, $p = .853$, Cohen's $d = 0.063$). A mixed ANOVA revealed a flanker × group ($F_{2,68} = 15.893$, $p < .0001$, $\eta 2p = .319$) and cue × flanker interactions ($F_{6,204} = 6.833$, $p < .0001$, $\eta 2p = .167$), and a main effect

of flanker ($F_{2,68} = 321.641$, $p < .0001$, $\eta2p = .904$) and cue ($F_{3,102} = 174.571$, $p < .0001$, $\eta2p = .837$). Interactions between cue × group ($F_{3,102} = 1.107$, $p = .350$, $\eta2p = .032$) and cue × flanker × group ($F_{6,204} = 1.012$, $p < .419$, $\eta2p = .029$) were not found. Post-hoc analyses using a two-tailed independent t-test revealed that musicians had average reaction times faster than non-musicians in the incongruent flanker condition ($t(34) = -3.076$, $p = .004$, Cohen's $d = 1.025$), showing that the attentional processing of the musicians was less disrupted by distracting stimuli than in non-musicians. Significant differences between groups in congruent and neutral flanker conditions were not found (congruent: $t(34) = -1.105$, $p = .277$, Cohen's $d = 0.368$; neutral: $t(34) = -1.113$, $p = .273$, Cohen's $d = 0.371$). As for the interaction between cue and flankers, Fig. 2 provides a clear visualization of the effect. A post-hoc analysis based on two-tailed paired t-test revealed that, across subjects, congruent and neutral trials received faster responses than incongruent trials in all cue conditions (inc vs. cong: ($t(35) = 15.906$, $p < .0001$, Cohen's $d = 2.651$; inc vs. neu: ($t(35) = 16.059$, $p < .0001$, Cohen's $d = 2.676$). Likewise, neutral trials elicited faster responses than congruent trials ($t(35) = 3.252$, $p = .003$, Cohen's $d = 0.542$). Also, the trials with spatial cue elicited faster responses than center, double and no cue trials (spatial vs. double: $t(35) = -9.446$, $p < .0001$, Cohen's $d = 1.574$; spatial vs. center: $t(35) = -12.176$, $p < .0001$, Cohen's $d = 2.029$; spatial vs. no cue: $t(35) = -19.286$, $p < .0001$, Cohen's $d = 3.214$). Center and double cue trials elicited faster responses than no cue trials (center vs. no cue: $t(35) = -9.197$, $p < .0001$, Cohen's $d = 1.532$; double vs. no cue: $t(35) = -12.520$, $p < .0001$, Cohen's $d = 2.086$), while double cue trials received faster responses than center cue trials ($t(35) = -6.379$, $p < .0001$, Cohen's $d = 1.063$).
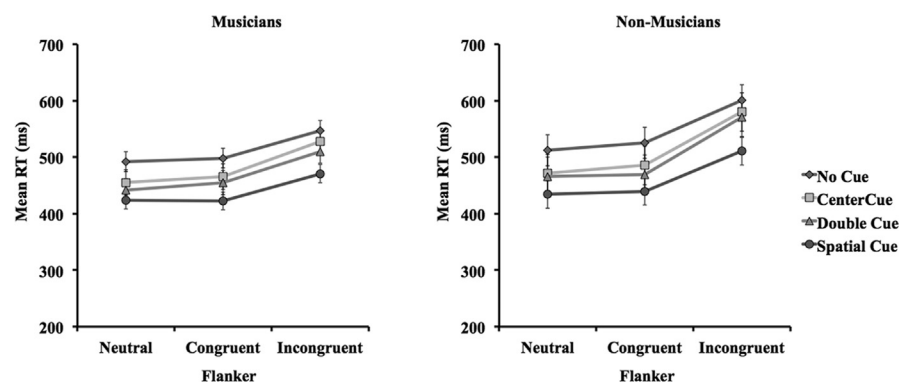

Fig. 2. Mean RTs from correct trials as a function of cue and flanker condition for musicians and non-musicians. Left and right graph represent the performance of musicians and non-musicians respectively. The y-axis and x-axis indicate the mean RT in milliseconds (ms) and flanker type. Lines showed to cue type. Error bar represents ± 2 standard errors.

3.2. Attentional networks efficiency

Results are shown in Fig. 3. Mean scores of the alerting, orienting, and executive networks for the musicians group were 43.84 ms, 43.70 ms, and 53.83 ms, while the mean scores for the non-musicians group were 41.98 ms, 51.56 ms, and 87.19 ms, respectively. A mixed ANOVA revealed a network $\times$ group interaction ($F_{2,68}$ = 6.068, p = .004, $\eta 2p$ = .151) and a main effect of network type ($F_{2,68}$ = 15.987, $p < .0001$, $\eta 2p = .320$). Post-hoc analyses based on two-tailed independent t-test showed that the executive network of musicians is more efficient than it non-musicians ($t(34) = -4.529$, $p < .0001$, Cohen's $d = 1.510$). No differences on the efficiency of the alerting and orienting network were found (Alerting: $t(34) = .273$, p = .786, Cohen's $d = .091$; Orienting: $t(34) = -1.005$, $p = .322$, Cohen's $d = .335$). Additionally, post-hoc analyses based on two-tailed paired t-test revealed that, across subjects, scores for the alerting and orienting networks are have lower than score for the executive network (alerting vs. executive: $t(35) = -4.896$, $p < .0001$, Cohen's $d = 0.816$; orienting vs. executive: $t(35) = -4.193$, $p < .0001$, Cohen's $d = 0.698$). Significant differences between the alerting and orienting networks were not found ($t(35) = -0.834$, $p = .410$, Cohen's $d = 0.139$).
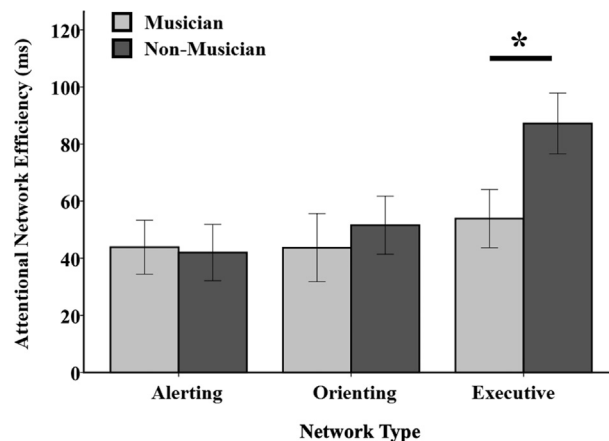

Fig. 3. The efficiency of attentional networks for musicians and non-musicians. Light gray and dark gray bars represent musicians and non-musicians respectively. The y-axis and x-axis indicate the mean efficiency in milliseconds (ms) and attentional network type. RTs differences are provided for the alerting (no cue−double cue), orienting (center cue−spatial cue) and executive attention (incongruent−congruent) networks. For the executive system, the higher scores show less efficient inhibitory attentional control. The asterisk represents significant differences between groups ($p < 0.05$). Error bar indicates $\pm$ 2 standard errors.

3.3. Correlation analysis

Years of musical training and efficiency of the executive network. Results are shown in Fig. 4. A bivariate Pearson correlation analysis revealed an association

between the efficiency of the executive attention network and years of professional musical practice (r (18) $= -.609, p = .007$) (Fig. 4). To further evaluate whether the link between years of musical training and efficiency of the executive attention network still holds after controlling for age as a confounding factor, we computed a partial correlation. The results showed that the relationship among the efficiency of the executive attention network and years of professional musical training remained significant even after controlling the effects of age (r (15) $= -.533, p = .028$).
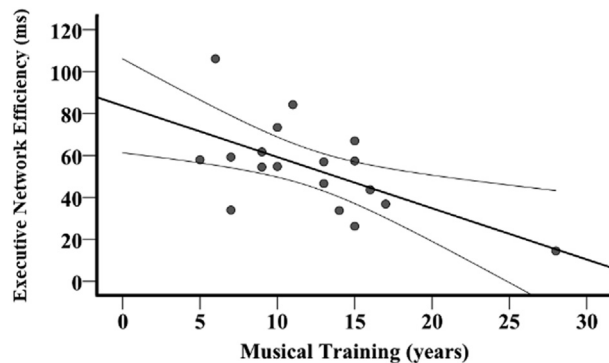

Fig. 4. Correlation between years of musical training and efficiency of the executive attentional network. On the y-axis, low scores show greater executive attention (incongruent−congruent) network efficiency. Curve lines represent 95% confidence intervals.

Independence of attentional networks. We also assessed the functional independence between the three attentional networks. As for musicians, a bivariate Pearson correlation analysis revealed a association among the alerting and orienting systems (r (18) $= -.488, p = .040$), but independence of the executive control networks both with the alerting (r (18) $= -.305, p = .219$) and orienting (r (18) $= .102, p = .687$) networks. As for non-musicians, the correlation analysis showed independence between the three attentional networks (alerting/orienting: r (18) $= .114, p = .651$; alerting/executive: r (18) $= .399, p = .101$; orienting/executive: r (18) $= .107, p = .672$).

4. Discussion

The present study was designed to examine the effect of systematic musical training on the efficiency of attentional networks. Our results showed that the executive control of attention is more efficient in musicians than non-musicians and that the years of musical training significantly improve the efficiency of the executive network. Additionally, we found that the efficiency of the musicians' alerting and orienting systems are functionally related. Below we discuss the principal findings and their implications in more detail.

4.1. Attentional networks efficiency

Behavioral data analysis revealed that compared to non-musicians, the musicians showed a faster and accurate response pattern when conflicting or distracting information was presented, which was supported by a higher efficiency of their attentional control network. Previous studies have linked the efficiency of attentional control network to increased monitoring-resolution of cognitive conflicts (Rothbart et al., 2007), sustained attention (Fan and Posner, 2004; Petersen and Posner, 2012), and working memory (Diamond, 2013). As for the role played by the executive attentional network during musical training, we propose that it is a crucial cognitive function for the acquisition, consolidation, and deployment of musical skills. For instance, when pianists play a musical excerpt, they put into action auditory-motor processing, along with other complex cognitive operations such as sustaining attention during the instrument's execution, filtering irrelevant stimuli or controlling intrusive thoughts affecting the interpretation, keeping in mind the past musical information to integrate incoming new information, paying attention to score and conductor, etc. These and other experiences associated with long-term musical training seem to require an efficient executive attentional system for optimal performance, which could be indicative of an indirect development of attentional control induced by musical training.

Considering the higher efficiency of the musicians' executive control network, we suggest a possible transfer effect induced by musical training. However, to establish a transfer of learning, it is necessary to prove that both the trained skill and the untrained skill not only recruit overlapping processes, but also engage shared brain regions (Dahlin et al., 2008). At a neurophysiological level, musical training not only increases cortical thickness of the auditory cortex (Gaser & Schlaug, 2003; Schneider et al., 2002), and motor regions (Bangert & Schlaug, 2006; Elbert et al., 1995) but also induces morphological changes in higher brain areas such as superior temporal and dorsolateral frontal regions (Bermudez et al., 2009). Interestingly, the dorsolateral prefrontal cortex is a key area for executive functions, particularly goal-oriented behavior (Balleine & O'doherty, 2010), error detection (Cavanagh et al., 2009), and working memory (Diamond, 2013). As for the attentional control network, the literature reports that this attentional mechanism involves the action of orbitofrontal, ventromedial and lateral prefrontal cortex, including the anterior cingulate and the amygdala (Bush et al., 2000; MacDonald et al., 2000; Raz, 2004). These findings, taken together, highlight the dorsolateral prefrontal cortex as an area sensitive to systematic musical training, and also as a key brain region for the attentional control system. Thus, we propose the dorsolateral prefrontal cortex as a potential shared brain region between music training and the executive attention network, which would support the proposal of a transfer effect of the musical training over the efficiency of the executive control network. Future longitudinal research should directly address these interpretations.

4.2. Years of musical training and efficiency of the executive network

The fact that inhibitory attentional control is more efficient in musicians than non-musicians is a promising finding because it could be a sign of transfer of learning induced by musical practice. However, it is important to stress that we cannot infer causality from the present study because our data were cross-sectional. Nevertheless, as Wan and Schlaug (2010) state, cross-sectional studies are a good starting point to enlighten the potential benefits of musical training, define the areas that might be enhanced, and to determine the power necessary to detect changes in longitudinal studies examining causal effects. A commonly used method to support the findings of cross-sectional studies comparing musicians and non-musicians is to establish whether the cognitive improvement of the musicians covariates with the years of musical training (Ho et al., 2003; Jakobson et al., 2003; Pantev et al., 1998). We conducted this analysis, and we found that the efficiency of the executive attention network enhances with the years of musical training. Importantly, this association between executive attentional efficiency and musical training was preserved even after controlling for musician age. This result suggests that the increase in the efficiency of inhibitory attentional control through the years of musical training is not be mediated by a developmental factor or the simple passage of time (Kraus and Chandrasekaran, 2010). However, it is still possible to argue that the differences between musicians and non-musicians could spring from an individual biological predisposition present among those who practice music professionally. Norton et al. (2005) tested this hypothesis directly, assessing a group of 70 children aged between 5-7 years, with 39 children about to start private piano lessons or stringed instruments lessons for personal interest, the remaining 31 children not taking part in any private music lessons. The results of the study revealed that there was no pre-existence of cognitive, auditory, motor or brain differences between both groups of children. According to Norton et al. (2005), these findings reject the thesis linking the structural brain differences between musicians and non-musicians with a biological predisposition. In sum, our results reveal an improvement in the efficiency of inhibitory attentional control as the years of professional musical practice increase, which adds evidence to the argument of potential development of extra-musical cognitive abilities derived from musical training. However, new studies should be conducted to establish if there is a causal relationship between the deliberate practice of music and the development of inhibitory attentional control, or if there is a third variable that could explain the association between them.

4.3. Correlation between alerting and orienting network in musicians

When analyzing the relationship between attentional networks in non-musicians, we found that the three networks were uncorrelated. Among musicians, however, we

found a negative correlation for the efficiency of the alerting and orienting networks, while the executive system remained uncorrelated. In general, the lack of correlation between networks is interpreted as a sign of independence between attentional subsystems (Fan et al., 2002; Raz, 2004). However, criticisms have been advanced about the alleged independence of attentional networks (MacLeod et al., 2010). In this regard, it has been suggested that, although attentional networks are anatomically independent, there is an important functional interplay between them in daily life, which could be modulated by environmental variables or characteristics of the study group (Fan et al., 2009; Posner and Rothbart, 2018; Wang & Fan, 2007). As for the functional dependence between the alerting and orienting networks, previous studies provide contradictory interpretations. For instance, Callejas et al. (2004; Callejas et al., 2005) proposed that alerting accelerates orienting mechanisms, while Fuentes and Campoy (2008) suggested that alertness improves, rather than accelerates, orienting effects. Recently, it has been suggested (Ge et al., 2013; Mahoney et al., 2010; Yin et al., 2013; Westlye et al., 2010) that the negative correlation between alerting and orienting system stem from the incremental effect of spatial, as compared to alerting, cues. To better understand the relationship between musicians' alerting and orienting networks, we conducted additional analyses by calculating the score of these networks based on the error rate. A bivariate Pearson correlation analysis revealed that the error rates of the alerting and orienting networks were uncorrelated ($r(18) = .011$, $p = .966$). The absence of a correlation between these networks, when using the error rate to calculate their scores, suggests that the dependence between musicians' alerting and orienting networks affects the efficiency but not the effectiveness of both systems. As for the mechanism underlying the negative correlation between the efficiency of both networks, we suggest that: (i) musical training moduletes the interdependence between both systems; (ii) visual stimuli that warn and guide attention (such as the spatial cue in the ANT task) trigger the coactivation of both systems (Wan and Fan, 2007); (iii) depending on the demands of the task, the action of one of the two networks is inhibited. The time between coactivation and the subsequent inhibition of one of the systems would affect efficiency, but not the effectiveness of the behavioral response, which could explain the negative correlation between musicians' alerting and orienting networks. Thus, we propose that systematic musical training might enhance the dynamic coupling between the alerting and orienting networks, fostering the development of more adaptive and flexible behaviors driven by the musical context demands. It is of the essence to conduct further studies that might shed light on the neurodynamic substrate of the musicians' alerting and orienting networks, and thus determining whether the association between these networks stem from a transient functional coupling of neural assemblies (Fan et al., 2007) or a structural overlap between both neural systems (Corbetta, 1998; Fan et al., 2009).

In summary, the present study contributes to previous research about extra-musical effects of musical training by proving that executive attention is more efficient in musicians than non-musicians. Additionally, we were able to establish that the efficiency of the executive network improves along with the years of musical training. Finally, we showed that the processes of alerting and attentional orientation of musicians are related, potentially being the basis of their rapid and efficient behavioral responses.

Declarations

Author contribution statement

David Medina: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Paulo Barraza: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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