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Cognitive differences between musicians and non-musicians

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1.Introduction

Listening to and practising music are very enjoyable and rewarding activities and it is commonly believed that music brings other advantages besides that of being a pleasurable activity. It often happens that educational figures encourage children to start playing a musical instrument, with the belief of enabling them to be engaged in something significant for their intellectual growth. The idea that music makes you smarter, indeed, is pretty popular and some research suggests that music practice seems to actually make you smarter: at least for what concerns “hearing intelligence” (Strait and Kraus, 2011b).

It is quite obvious to think that persistent music practice leads to enhancements in musical abilities; it is not that obvious, though, to believe that practising such a specific ability could bring benefits to other domains, such as to complex cognitive functions like intelligence. For this reason, over the last years, the idea that playing a musical instrument could lead to various benefits started to be scientifically relevant as well and, as a consequence, musicians have become subjects of great interest in psychology.

The aim of the present work is to try to understand if and how music extends its effect outside the field of expertise, giving in some instances benefits to other, apparently unrelated domains. The evidence on our possession concerning this topic, gathered over the years by an ever increasing scientific literature, will be deeply analysed, with a focus on the reliability of the results we examine.

2. Effects of music practice

Many studies showed that music practice firstly induces functional, structural, and behavioural changes closely finalised to music performance (Schlaug et al., 2005) and eventually, after a prolonged period of practice, these changes could extend to other areas, even if the mechanisms by which this happens are mostly yet to be defined.

The main structural changes found in musicians have been located in those regions of the brain linked to such skills, which are closely finalised to music execution (Schlaug et al., 2005). These domain-specific skills can be summed up in the abilities of converting visual symbols into complex movements, memorising elaborate musical scores, improvising and identifying tones with the presence of a reference tone (relative pitch) or without it (absolute pitch) (Gaser & Schlaug, 2003). Interestingly, structural differences outside the regions implicated in the execution of these tasks have been found, and it has been hypothesised that they could serve as multimodal integration regions for musical skills (Hyde et al., 2009). In fact, given that playing a musical instrument demands a huge variety of skills, the so-called transfer effects appear to arise and provoke, as a consequence, changes in other areas. These music-induced changes can be categorised in three different levels: the ones related to the field of expertise, namely the changes that allow musicians to play an instrument; that others closely related to music practice, known as “near transfer” skills, like enhancements in listening and fine motor skills; and lastly the ones not directly related, which are those where the relation between musical practice and the specific transfer domain is not obvious (Hyde et al., 2009), such as intelligence improvements.

Some studies suggest that these changes are due to neuroplasticity, defined as an intrinsic property by which the acquisition of new skills and memories is possible as a consequence of perception and motor actions (Pascual-Leone, 2001); they suggest that it is induced by repeated and persistent musical practice (nurture). Indeed, playing a musical instrument requires highly specialised sensorimotor, auditory and auditory-spatial skills (Schlaug et al., 2005), and, to yield these ability changes, the brain needs to adapt itself to a new structural and functional configuration through the aforementioned experience-based plasticity. This process begins with instrumental practice, and the size of the consequent changes seems to be proportional with duration and intensity of individuals' musical training and the age of the first approach to musical studies (Schlaug et al., 2005). Other hypotheses instead argue that these differences are due to biological predisposition, thus innate musical interest or pre-existing aptitude (nature) (Hyde et al., 2009). A longitudinal study conducted by Schlaug and colleagues (2005) found no pre-existing cognitive and structural differences between musicians and non-musicians: this suggests that musical training could be the main cause of these differences, rather than the existence of innate musical markers. As previously mentioned, these plastic changes have been mostly located in those regions which are thought to be related to music performance, such as the premotor and the sensorimotor cortex, even though some evidence showed that other areas are involved as well, suggesting that cognitive functions may be affected too.

In the next chapter, the cognitive differences between musicians and non-musicians will be discussed, with a particular focus on perception, attention, memory, and intelligence. Given their different degree of complexity this paper will begin analysing the simplest, which is perception, moving further to attention, memory, and finally intelligence.

3. Cognitive differences

Musicians spend a consistent amount of time in order to master the craft of playing an instrument, being able to reach all the perceptual, attentional and cognitive skills that are required (Carey et al., 2015). As anticipated before, music training is thought to be the cause of some non-music improvements, which are not directly finalised to music performance: some evidence highlights that these changes extend to cognitive domains as well, such as perception, attention, memory and intelligence (Schlaug et al., 2005; Schellemberg et al., 2006; Carey et al., 2015).

It is still to be defined whether these changes are actually due to music practice or to other factors, such as individuals' differences or publication biases. Much evidence on our possession, that contributed to spreading the idea that music gives many benefits, seems to be poorly controlled (Strait and Kraus, 2011b). For this reason, every research we will take into account will be analysed carefully, trying to consider all the factors that could have contributed to the obtained results. Hereafter we will analyse the relation between music practice and auditory perception.

3.1 Auditory perception

Perception is the cognitive ability that enables us to recognise, observe and discriminate our surroundings through the senses, making us aware of them. In particular, auditory perception can be defined as the "organisation and interpretation of sensory information received through the ear" (APA, n.d.).

Before start discussing this topic, it is important to note that human hearing processing can be divided into peripheral and central: the peripheral hearing processing involves the outer, middle and inner ear, and it cannot be modified by music practice, given that it is only composed by mechanical unites; on the other hand, central hearing processing, which starts from the cochlear nucleus up to the primary auditory cortex, can be modified by training, due to brain's plastic potential. We will therefore take into consideration the central hearing processing, which is the only one in which changes due to practice can be seen.

Perception is one of the cognitive abilities in which the consequences and eventually the improvements consequent to musical training are more evident: when practising, musicians face huge perceptual demands. They need to perceive and control their instrument output and, at the same time, if accompanied by other musicians, have to pay attention to their outputs as well (Carey et al., 2015).

We will now analyse an experiment in which children have been recruited as subjects, and this could give a good example of brain plasticity induced by training, because children's brains have the highest plasticity potential. In fact, humans' brain is not completely mature up to about 20 years old, and it is characterised by critical periods, which are maturational time periods in which the plasticity potential of the brain is the highest for a specific skill; hence, learning from new experiences during these time windows has its maximum effectiveness on the acquisition of new skills (Mundkur, 2005).

Hyde and colleagues (2009) conducted an experiment in which they recruited two groups of children who had never taken music lessons before: one group started following keyboard lessons for about 15 months; the other group did not received any instrumental training, except for attending a music class of less than an hour, once per week, in which they sang and played drums and bells. They then tested children's structural brain changes after 15 months of instrumental practice: they found differences in the instrumental group compared to the control one, who were not present at baseline, in the auditory areas, which were linked to improved auditory melodic and rhythmic discrimination skills. This experiment constitutes evidence consistent with the idea that perceptual differences found in musicians are likely to be related to music training rather than to other innate factors.

Moreover, it has been shown that musicians have lower perceptual thresholds for what concerns frequency discrimination and backward masking measures compared to non-musicians (Strait et al., 2010). Backward masking can be defined as the partial or complete obscuring of a stimulus in the presence of a masker, that is presented shortly afterward (APA, n.d.). For this experiment, Strait and her colleagues recruited adult musicians and non-musicians and tested them with a battery of perceptual and cognitive tasks, under the assumption that musicians have better sensitivity in frequency discrimination and temporal processing. They found that musicians are better in discriminating frequency than non-musicians, besides of outperfoming them in all the backward masking's measures. Additionally, this study evidenced a relationship between auditory and cognitive abilities in musicians that was not present in non-musicians: this could be explained by the more efficient neural mechanisms implicated in auditory processing owed by musicians.

Another experiment in which perceptual differences between musicians and non-musicians have been investigated was conducted by Carey and colleagues (2015). They recruited violinists, pianists and non-musicians to investigate whether there were differences in their auditory performances: three different groups were recruited in order to understand if music training demands bring specific or general perceptive advantages. The experimenters measured their auditory thresholds by using a battery of auditory psychophysical tasks, consisting of the discrimination of the onset envelope rise time, the detection of amplitude modulation and of frequency modulation. Pianists and violinists performed better than non-musicians in the three tasks presented above. They did show a similar perceptual sensitivity, even though violinists were expected to show superior sensitivity in amplitude and frequency modulation, because of their need to manipulate pitch’s depth and amplitude modulation when playing the violin, which is not something that concerns pianists. Similarly, pianists' ability to perceive fine differences in rise times did not differ from violinists’: the former were expected to outperform the latter, given that their primary expressive tools are attack and decay envelope. Hence, even if pianists and violinists manipulated these variables in different ways, they showed similar perceptual sensitivity, which was nevertheless better compared to non-musicians.

We will now briefly talk about an auditory ability that characterises only a few professional musicians: the absolute pitch. Absolute pitch can be defined as the rare ability to perceive and identify tones absolutely, in the absence of an external reference tone (APA, n.d.). Only a small portion of the musicians population own this skill and it is very unlikely for musicians who did not start practising at a young age to possess it, as it appears fundamental to start learning music during specific critical developmental periods. It has been shown that the majority of musicians with absolute pitch have indeed started practising before the age of seven years old (Schlaug et al. 2001). In addition, musicians with absolute pitch show both structural and functional differences when compared with their counterparts without it, like greater left-sided asymmetry and activation of the planum temporale, which is a fundamental structure involved in sound processing (Schlaug et al., 2001).

Until now, we discussed the perceptual differences between musicians and non-musicians mainly for what concerns the field of expertise. We will now talk about an experiment in which perceptual differences between these two categories have been taken into account, focusing on the “near-transfer” effects as well.

Strait and Kraus (2011b) conducted a research with the aim of investigating whether music training shapes auditory abilities not directly finalised to music performance, such as language-related abilities. The fundamental idea was that musicians have better auditory perceptual skills and sound processing in any domain, with consequent improvements on language abilities as well, such as speech and reading. This study suggests that music training makes musicians better listeners, in the way they perceive and neurally process sound, even outside the music domain, probably thanks to their better sensitivity to pitch and the temporal components of both language and music (Strait & Kraus, 2011b).

Now that we discussed the role of perception in musical training and the ability changes due to it, we will analyse another cognitive ability which is strictly involved in music practice, attention.

3.2 Attention

Attention can be defined as “a state in which cognitive resources are focused on certain aspects of the environment rather than on others” (APA, n.d.). It is the mechanism by which the elaboration of a particular stimulus or the execution of a specific cognitive process are privileged. Even just thanks to these definitions, it is easy to understand how fundamental attention is for practising a musical instrument: in fact, musicians have to sustain their attention towards certain stimuli for prolonged periods of time while practising or performing, selecting the relevant sounds in the most efficient and quick way (Carey et al., 2015). Without sustaining attention, it would not be possible for musicians to succeed in monitoring frequency and harmonic and temporal features (Carey et al., 2015), which are fundamental tasks to make a sonata possible.

Much evidence suggests that music training plays a role in enhancing our ability to direct attention: it has been found that musicians have faster reaction times during auditory sustained attention tasks compared to non-musicians (Strait & Kraus, 2011a). The same study analysing speech in noise tasks, which are composed by signals presented in a challenging listening environment, found a relation between the ability to discriminate target signals avoiding competing noises, which is a fundamental ability that allows us to communicate and to perceive and select sounds efficiently in our everyday lives, and auditory attention performance (Strait & Kraus, 2011a). In fact these kinds of tasks require many attentional resources that seem to be enhanced in highly trained musicians (Strait & Kraus, 2010).

Strait and her colleagues (2010) conducted another experiment in which they studied, among other measures, auditory and visual attention. They administered several attention tasks that measured phasic alertness by comparing participants' reaction times when a target stimulus was presented by itself and when anticipated by a cue. Musicians performed better than non-musicians when tested with these tasks, suggesting that musical training induces attentional improvements, especially to auditory attention, related to several tasks such as better reaction times.

We will now take into consideration some studies regarding musicians' sustained attention, which is an attentive state towards a certain stimulus or mental operation that lasts for an extended length of time (APA, n.d.). Several studies showed that musicians outperform their untrained counterparts in sustained attention for what concerns the auditory domain but not the visual one (Wang et al., 2015). Carey and her colleagues (2015), in the experiment we analysed above on perception, investigated attention as well: they evaluated whether individual differences play a role in the perception of changes of basic acoustic features. They then inquire whether musicians' attentional skills finalised to music performance could extend to non-music domains as well. To do so, they tested musicians' sustained attention abilities, both during practice and performance, recruiting, as anticipated in the previous paragraph, violinists, pianists and non-musicians. Participants were tested with the "Sustained Auditory Attention to Response Task" (SAART), that is a speeded response switching task. They discovered little differences between musicians (violinists and pianists) and non-musicians in auditory sustained attention. They found sustained attention to be a predictor of the variance of amplitude modulation depth thresholds, which indicates that auditory attention skills could contribute to fine acoustic perception.

While the relation between improved auditory attention and musical training is quite obvious, the transfer of these improvements to visual attention is less easy to think about. When a musician plays a musical instrument though, especially during ensemble practice, he needs visual information as well: to follow the music score, to synchronise with the other musicians and to obtain expressive information from them. Hereafter, we will consider some literature regarding visual attention with the purpose of understanding whether this domain is affected by musical practice as well (Clayton et al., 2016).

A study investigated musicians' sustained attention using both visual and temporal tasks, with the aim of demonstrating their better performance in general attention tasks compared to non-musicians (Wang et al., 2015). Two groups of participants were recruited, a musicians' group and a control one. The experiment partially confirmed researchers' hypothesis: musicians have been found to outperform their untrained counterparts as for temporal tasks, but not for the visual ones, which are less related with music training. Musicians' better performance in timing-based tasks could be the result of persistent music training that leads to improved temporal discrimination abilities (Rammsayer & Altenmüller, 2006). The possibility that these differences come from musicians' pre-existing timing abilities that could have helped them to succeed in music, though, cannot be excluded.

Contrary to the findings of the previous study, Rodrigues and her colleagues (2013), actually found visual attention differences between musicians and non-musicians. The aim of their study was to discover whether long-term intensive musical training brings advantages in different domains of visual attention. Given that playing a musical instrument requires many visual attention demands, the authors decided to include selective, divided and sustained attention measures, using neuropsychological tests in order to obtain a comprehensive view. They recruited a group of musicians from two Brazilian Symphony Orchestras and a control group. The experiment found differences between musicians and non-musicians for all the three measures, indicating that musical practice could be the cause of visual attention's improvements as well. The results regarding divided visual attention are in line with the fact that musicians, during ensemble musical practice, need to pay attention to their instrument, to the other players' or conductor's movements and performance and, in the meantime, have to read the music scores as well. On the other hand, musicians' better sustained attention performance could be related to the fact that when they play, for example during concerts, they need to sustain their attention for prolonged periods of time to guarantee an efficient performance. Whereas for what concerns selective attention, the results seem to evidence the need of musicians to pay attention to details when playing.

After having examined the possible effects of music practice on attention, we will continue on this way exploring other cognitive domains, analysing now some literature about memory.

3.3 Memory

As we anticipated before, playing a musical instrument requires a variety of different skills: besides specific motor abilities, fine auditory perception, focused attention, the ability to maintain different types of information in both short-term and long-term memory are needed to play music (Dittinger et al., 2021). We will therefore investigate deeper whether, and at which level, music training induces memory' abilities changes. First of all, it is important to define memory, which is "the ability to retain information or the representation of past experience, based on the mental processes of learning or encoding, retention across some interval of time, and retrieval or reactivation of the memory" (APA, n.d.). Several studies were made to investigate whether music learning affects working, short-term, and long-term memory, and the results suggest that musicians outperform non-musicians on these abilities.

In 2011 an experiment studied the relationship between working memory and musical training (George & Coch, 2011). The researchers administered to participants, who were both musicians and non-musicians, standardised working memory tests, which were composed of visual, phonological, and executive memory subtests. In addition, an electrophysiological measure was made recording the event-related potentials, when participants were tested with a classic oddball paradigm, consisting of two auditory and two visual paradigms. This experiment demonstrated, electrophysiologically and behaviourally, that music training induces working memory's enhancements in both visual and auditory domains. From the authors' knowledge, this is the first study that took into consideration both behavioural and electrophysiological measures finalised to examining working memory processing in relation with long-term musical training.

Another experiment was run in 2011 by Cohen and his colleagues, in which they tested participants' visual and auditory memory, with the aim of understanding whether highly trained musicians show ability changes in these two domains. They administered to a group of musicians and one of non-musicians, auditory and visual recognition tasks, using different stimuli, who were familiar or unfamiliar to the participants. Thanks to this experiment, the researchers found musicians to be better than non-musicians for what concerns auditory memory, when both exposed to music-related and non-musical sounds. Whereas no significant differences have been found between musicians and their untrained counterparts when tested with visual memory's tasks. It is important to note though, that in general both groups performed better in the visual tasks, probably because the visual modality is the predominant one in humans (Cohen et al., 2011).

A meta-analysis conducted by Talamini and colleagues (2017) found some significant results concerning short-term, working and long-term memory, that were specifically related to the type of stimuli presented in the studies that were taken into account. In general, it has been shown that musicians exceed non-musicians when tested with music-relevant tasks, such as recall of tonal stimuli. As for what concerns working memory, the present meta-analysis found a moderate effect size, indicating the superiority of musicians over non-musicians. Musicians appear to perform better when exposed to music-related stimuli and, surprisingly, also in the case of verbal stimuli. No significant differences were found between these two categories when tested with visuo-spatial tasks. Quite significant results were found for short-term memory as well: musicians showed better performance than non-musicians, with a moderate effect-size, in shortmemory tasks, in the music-specific, verbal, and also visuo-spatial domains. On the contrary, the results on long-term memory have been found to be less significant compared to the ones regarding working and short-term memory. It is important to note that none of the studies that have been considered for long-term memory, except one, included music-relevant stimuli: this could be the reason why the differences between musicians' and non-musicians' performances were less significant when evaluating long-term memory. The difference of significance found in working and short-term memory compared to long-term memory, could suggest that improvements due to music training are more likely to occur for short-term and working memory. The superiority of musicians as regards to music-related tasks can be explained with their familiarity to such kinds of stimuli; it is still unclear though why these changes occur in the verbal and visuo-spatial domains. However, musicians' better performance, found with verbal stimuli, could be explained by musicians' auditory skills, which as examined in the previous paragraph have been found to be enhanced thanks to musical training. From this evidence, it can be concluded that musicians generally have better memory than non-musicians. It should be noted that, among the studies taken into account by this meta-analysis, there were many that have not found any superiority of musicians' performance.

A more recent study, subsequent to the metanalysis, investigated long-term memory differences between musicians and non-musicians (Dittinger et al., 2021). As with the majority of the experiments we analysed, they recruited a group of professional musicians and a control one, formed by non-musicians, in order to investigate whether music training affects long-term memory as well. They chose novel word learning as the main task, given that it requires both perceptual and cognitive abilities. The research was composed of several phases, including phonological categorizations tasks, thus matching and semantic tasks, a session of picture-word learning and a test phase, which was done one month after the other experiments; the latter is in particular the phase of our interest. In this last part, the participants were tested with the same tasks mentioned before (matching and semantic tasks), giving a measure of musicians and non-musicians' long-term memory abilities. They found out that musicians, after a one month period, remembered better the picture-word associations than non-musicians, which could be the consequence of musicians' better working memory that creates stronger memory traces facilitating then the recall after a while. This study provides evidence that music practice could induce long-term memory changes as well.

Future research should investigate deeper whether these differences are actually due to music practice or due to other factors, given that these results may be the consequence of many biases, such as individual differences and publication biases.

3.4 Intelligence

Understanding whether music practice affects complex cognitive functions such as intelligence has been a topic of great interest and debate in the last hundred years in psychology (Costagiomi, 2014). Even though many studies have found a relation between instrumental practice and various intelligence measures, they do not seem to be enough to determine causal relationships between these two variables.

Hereafter, we will take into account some studies in which the Wechsler Intelligence Scales have been employed. They are the most widely used intelligence tests and comprehend many sub-tests that include domains such as verbal ability, spatial ability, processing speed, and working memory (Schellemberg & Weiss, 2013).

One study was conducted in order to investigate whether a positive relation exists between general intelligence and the duration of music lessons (Schellemberg, 2006). Children, from 6 to 11 years old, with different musical backgrounds, were recruited and tested with the third edition of the Wechsler Intelligence Scale for Children, to obtain a comprehensive measure of children' general intelligence. They then evaluated their applied intellectual functioning, with measures such as school' grades and a standardised test for academic achievement. Thanks to this experiment, music lessons that were measured considering their duration in months, have been found to be related with all the intelligence' measures and academic achievement; this association, though, cannot be solely attributed to music practice, given that there may have been present confounding variables that have not been taken into account, which could have played a role.

Schlaug and his colleagues (2005) ran an experiment in order to investigate, among the other objectives, whether music practice brings benefits in the intelligence domain. They tested children from 5 to 7 years old before and after they started practising a musical instrument (piano and string) and a control group, composed by children who did not play any musical instrument, who were matched with the experimental group before the beginning of the instrumental practice for SES (socio-economic standard), verbal IQ, and age. Before starting instrumental practice, children were tested with a battery of behavioural tests, among other measures, such as the Wechsler Intelligence Scale for Children or the Wechsler Preschool (WISC-III) and Primary Intelligence Scale (WPPSI-III) for children younger than 6 years old, Raven's Colored Progressive Matrices (CPM), Raven's Standard Progressive Matrices (SPM), and the Gordon's Primary Measures of Music Audiation (PMMA) in order to measure their music aptitude. Thanks to these tests they found no pre-existing cognitive or music aptitude differences between the two groups. After one year of instrumental practice, the researchers have found differences between the instrumental group and the control one for what concerns the behavioural tests strictly related to musical practice, but not for the other measures. This highlights that, after one year of practice, no significant transfer effects occur in the general intelligence domain, even if they found some evidence suggesting that the instrumental group was going in that direction. The same researchers after a few years, added a section to their longitudinal study, in which they tested, with the same battery of tests presented before, instrumentalists with at least 4 years of experience, from 9 to 11 years old, with a matched control group. They found musicians to outperform non-musicians in the PMMA, as expected, and in the Vocabulary subtest of the WISC-III, partially confirming researchers' hypothesis that long-lasting musical practice could induce transfer effects in domains not directly related to instrumental practice.

Moreno and colleagues, in 2011, conducted a study with the purpose of investigating whether short-term music and art training is related with enhancements respectively in verbal and spatial intelligence and executive functions. They recruited two groups of children, from 4 to 6 years old, one of which was undergoing a visual art training program or a music one, in which the only difference was the content. Children followed one hour training sessions, twice per day, five times per week, for one month. They were then tested with the WPPSI-III, in order to obtain a measure of visual and spatial intellectual functioning. Executive functions were measured as well, with the use of a go-nogo task, during which behavioural performance and event-related potentials were measured. Parents were then asked to fill a background questionnaire, which gave information about children's previous art or music training, and mothers' educational level. The experiment consisted of three phases, the pretest, the training phase, and the posttest: in both the pretest and posttest, the WPPSI-III and the go-nogo task were administered, to acquire a measure before and after the training. They found significant intelligence enhancements in musicians after one month of training, specific to verbal intelligence: this effect was seen in more than the 90% of the children who participated in the music program. Non-significant enhancements have been seen in the art group, for both of the domains. In addition, the music group performed better in the go-nogo task of the post-test than before the training, and they observed brain changes related with the improved performance in the intelligence posttest. These results provide evidence consistent with the idea that music practice could lead to enhancements which are not apparently finalised to music practice, besides highlighting a possible link between music and language in cognition.

Therefore, to try to understand whether there are mediators in the association between music practice and intelligence, we will analyse a study in which executive functions have been considered to be the conductive of these improvements. In 2011 Degè and colleagues conducted an experiment in which they tested children from 9 to 11 years old, with different levels of music experience, using the attentional and executive functions' measure of the developmental neurological assessment for children (NEPSY II). Among the executive functions measured by the NEPSY II, there were planning, fluency, set shifting, inhibition, and selective attention. Fluid intelligence was then measured with the use of a revised form of the Culture Fair Test. They found IQ to be significantly associated with the extent of music lessons and they confirmed the hypothesis that executive functions serve as mediators between music practice and intelligence. This finding indicates that the relation may be indirect, rather than direct, as it was hypothesised by the previous studies.

Since most of the literature found intelligence differences between musicians and non-musicians as regards to children (see the articles mentioned above), most recently, a study was made to investigate whether these effects can be found in adult musicians as well (Criscuolo et al., 2019). They tested both musicians and non-musicians with the Wechsler Adult Intelligence Scale III (WAIS-III), the Wechsler Memory Scale III (WMS-III) and the Stroop Test and matched them for SES (socio-economic status) and personal traits, among other demographic variables. They found a positive relationship between the level of musical expertise and general intelligence, verbal memory, working memory and attention. This suggests that persistent and prolonged music practice could lead to benefits in the aforementioned domains.

4. Conclusions

In the present work, we firstly analysed the direct effects of music practice and then moved further to the potential cognitive ones. After having finished analysing articles about the cognitive differences between musicians and non-musicians, hoping of having included all the relevant research in this field, it is evident that the results we examined do not provide a univocal conclusion and in some instances, we even found contradictory results.

As for perception and attention, differences between musicians and non-musicians have been found in the literature providing quite significant results, indicating musicians' superiority on these two cognitive domains, in particular related to music-relevant abilities. Quite significant results were present for memory as well, even if some research found no differences between musicians and non-musicians in this domain. As for intelligence, the results found are even more contradictory and seem to be poorly controlled, it is not easy then to interpret them. Furthermore, a complex cognitive function like intelligence is very difficult to study, given that it can be affected by many variables that cannot be controlled or predicted.

It is important to shed light on some issues that could have contributed to the examined findings. First of all, investigating cognitive abilities' changes in relation to music practice does not allow us to obtain results that can be solely attributed to music practice. Many confounding variables may have been present and played a role in the results. Given that many of the experiments we analysed recruited children as participants, we will give an example of the possible variables that may play a role when examining young people: there are some children who show interest in pursuing a musical career while others do not, some of them start practising and then quit while others continue, some others instead are pushed by parents to start playing and others do not have an external incentives (Costa-Giomi, 2014); so it is challenging to check up on many variables when doing research in this field. Variables such as economic status, personal traits and family education and structure may influence as well and cannot be controlled by researchers.

We can conclude then that the results obtained by the research we took into account cannot establish a direct relationship between music practice and intelligence. As we said with regard to the previous paragraphs, individual differences, such as higher IQ, can be predictors of musical achievements instead of being a consequence (Costagiomi, 2015). To delineate such a conclusion, other types of experimental design should be employed: for example a way to try to casually determine a relation between cognitive improvements and musical training would be longitudinal studies, in which all the possible variables that may play a role are measured prior and after the beginning of instrumental practice and the cognitive abilities as well, like in the study we considered above (Schlaug et al., 2005).

The problem with this kind of studies is that they are not that easy to conduct, given that many years are needed and many variables that cannot be predicted, may play a role in the meantime. In summary we can tell that the existing literature regarding the relation between music practice and cognitive functions' changes do not provide a univocal direction. Future research in this field should employ more efficient experimental designs in order to obtain more significant results.

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