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Are music-based interventions a way to improve executive function in autism?

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Abstract

Executive functions (EFs) play a vital part in planning and organising everyday life, and they are directly linked to tasks like problem solving and language skills. Furthermore, weaknesses in EF are frequent in individuals with autism spectrum disorders (ASDs). Since music therapy is gaining popularity as a treatment and education technique with this population, it seems important to examine its effects on EFs. This study seeks to evaluate the potential of music-based interventions to influence EFs, and to discuss its value in music therapy and special education research. A total of 12 studies were included in the research. As most research is focused on active music making in healthy subjects, its effects on EF in autism must be deduced and discussed based on the literature. The findings of this study can contribute to open new perspectives in music therapy research, and to create innovative approaches for children with ASD.

Keywords: Executive function, autism, music therapy, special education.

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1. Introduction

Even before there was an official diagnosis for autism which was published in the third edition of the DSM in 1980, music therapy interventions were already with this population since the 1940s. In fact, both the diagnosis of autism and the profession of music therapy, emerged simultaneously (Reschke-Hernandez, 2011). Among the first literature on autism (Kanner, 1943), the distinct interest of children with what was later to be called autism spectrum disorders (ASDs) in music is mentioned (Hollander & Juhrs, 1974). More recent research reports the beneficial effects of music therapy on various problems correlated with autism, like mood, aggressive behaviour, nonverbal communication and social skills (Shi, Lin & Xie, 2016). According to one of the most accredited theories, symptoms in autism are caused by a weak performance of executive functions (EFs). Consequently, it might be possible that the improvements observed in music therapeutical settings are caused by a music typical characteristic to augment or to train EFs in populations with ASDs. To investigate this hypothesis, a review on the effects of music on EFs is conducted and compared to the literature on EFs in autism. Two different types of studies are included in this review: The studies that search for correlations between musical abilities and EF (*correlation studies*), and the studies that observe the effect of an intervention over a period of time (*intervention studies*). Combining these two allows to observe the situation from different perspectives creating a completer picture of the potential of music therapy.

2. Background

ASDs are a group of neurodevelopmental disorders on a continuum ranging from mild to severe. This concept reflects the understanding that autistic traits may also be present in other psychopathological entities (Steinhausen, 2012). According to the DSM-5, the standard classification manual for mental disorders, the symptoms include areas of impairment in the social-communication and behavioural domain like special interests and repetitive behaviours, which start to occur in early childhood but a diagnosis can also be received later in life (Lauritsen, 2013). Language delay is no longer included for applying a diagnosis among the new criteria in the DSM-5 because language delay is not specific to ASDs, in fact, several children with language delay and a diagnosis of ASD develop fluent speech as they grow up (Lauritsen, 2013).

EFs cover a wide variety of cognitive skills. They are important for planning behaviour, setting priorities, impulse control, adapting to unexpected challenges, focusing and changing perspectives within a task or conversation. These mental processes are divided into three core EFs – inhibition (Miyake et al., 2000), working memory (Baddeley, 2010) and cognitive flexibility (Davidson, Amso, Anderson & Diamond, 2006) – from which higher-order EFs – like reasoning and problem solving – are built (Diamond, 2013). In short, they are essential for a self-determined, independent life. EF weaknesses in ASDs are documented by Granader et al. (2014) for example, who report globally elevated EF problems in children on the spectrum. They notice difficulties especially with the ability to adapt to new situations, to accept changes and to switch attention. Another study found profound decreases in adaptive functioning and adaptive skills in high-functioning preschoolers diagnosed with autism (Mclean, Johnson, Zimak, Joseph & Morrow, 2014), and the meta-analysis by Demetriou et al. (2017) suggests that populations with ASD show an overall impairment in EF.

Music therapy is a therapeutic approach that uses music to achieve therapeutic goals. It is defined as 'a reflexive process wherein the therapist helps the client to optimise the client's health, using various facets of music experience and the relationships formed through them as the impetus for change. As defined here, music therapy is the professional practice component of the discipline, which informs and is informed by theory and research' (Bruscia, 2013). In a therapeutical context it is used, for example, to improve language skills (Lim & Draper, 2011), address problem behaviour (Boso, Emanuele, Minazzi, Abbamonte & Politi, 2007; Lanovaz & Huxley, 2017), nonverbal communication (Gattino, Riesgo, Longo, Leite & Faccini, 2011) and social skills (Shi, Lin & Xie, 2016). Historically, musical interventions have been applied since the 1940s to ease communication problems and to

improve well-being in people with behavioural disorders, part of which would later be diagnosed with autism. Beginning with trial and error approaches, music therapy research slowly moved on to evidence-based methods which are always adapting to the changing and growing understanding of autism as a disorder and as a diagnosis (Reschke-Hernandez, 2011). Nowadays, music therapy is facing a growing popularity in clinical and educational contexts (Holmes, 2011), and an increasing number of studies document the effect of music therapy on people with ASDs.

With regard to the effectiveness of music therapy on EF, it is worth mentioning that there are only a very few studies on this subject to date. An initiate literature research on the 28 November 2017 using the databases ScienceDirect, PubMed, ERIC and Springer Link found that only three studies were discussing about music therapy and EFs (Shimizu, Umemura, Matsunaga & Hirai, 2017; Siepsiak & Krejtz, 2016; Thaut et al., 2009), of which none targets ASDs. Notably, the only music therapeutical approach utilised in these studies is neurologic music therapy (Thaut, Hoemberg & Von Wild, 2014), an approach that uses evidence-based methods in therapy and research, and that connects music therapy to neurological approaches.

3. Method

A literature research is conducted, using the databases Science Direct, Cochrane, PubMed, ERIC, Google Scholar and RomaTreDiscovery, applying the keywords 'executive function', 'cognitive control' and 'executive control' in order to cover EFs, as well as 'music', 'rhythm' and 'instrument lessons' to include as many music-based interventions as possible. In order to present EF as a whole, the literature researches were made for the general terms and excluding searches for specific components of EFs like working memory or inhibition. A total of 25 studies have been identified on the basis of title and abstract. 12 studies were included in the research after reading of the full articles.

Six of the studies investigate correlations between musical abilities and EF, which are mostly evaluated in a single session – in the following they are called *correlation studies*. The other six studies focus on the effect of a music educational or therapeutical intervention and observe its effects on subjects over time – they are referred to as *intervention studies*. By comparing these two types of studies, a broader picture of the impact of music on EF is to be achieved, since it is often not clear, which condition causes the other: are people with high EFs more likely to be interested in music, or do musical activities influence EFs? *Intervention studies* are very useful at this point, because when applying an intervention to two comparable groups, their skills develop differently over the course of the study and it might be possible to find evidence concerning causality. Each study is analysed for a type of musical intervention, age and pathology of subjects, setting, measuring method and duration/frequency of interventions. The results are then compared to each other.

3.1. Results for correlation studies

Six articles work on the correlation of musical abilities and EF, of which one article covers two studies by applying the same study design to two different age groups – children and adults (Zuk, Benjamin, Kenyon & Gaab, 2014). Because of this considerable difference in age groups, these are listed as two studies (Table 1, Table 2). All articles have been published after 2008, and use a control group design. Mostly, the EFs of healthy individuals with different musical backgrounds are compared. Only one study associates children with a EF deficit to a healthy control group searching for differences in musical perception (Lesiuk, 2015). Two articles include linguistic aspects: Bialystok and DePape (2009) as well as Moradzadeh, Blumenthal and Wiseheart (2015) compare the EFs in musicians and bilinguals to those in non-musicians and monolinguals. The age groups are balanced, with three adult age groups (18–35 and 18–29 respectively) and three groups of children (9–12 and 9–11 respectively). One study does not provide any data on age. The number of participants ranges between 27 and 153, but only half of the articles take the social-economic status of their subjects into consideration as an influencing factor: Moradzadeh et al. (2015), Schellenberg (2011) and Zuk et al. (2014). Economic circumstances could contribute notably to the outcome of scientific tests: Wealth

allows for expanded cognitive and social stimulation, whether by enabling more hobbies, higher quality of leisure activities or better education. This extended stimulation might influence the cognitive abilities of the subjects and have effects on the frequency and quality of musical instruction or the motivation to participate in it. Research on the cognitive development and academic achievement in children of lower income families backs this idea up (Evans & Rosenbaum, 2008). Thus, it might be necessary for future research to include further information on personal and/or family income.

Table 1. Details on the samples

Study	Age	*N*	Experimental group	Control group	Testing for
Bialystok and DePape (2009)	18–35	95	Bilinguals & musicians	Monolinguals & non-musicians	EF
Clayton et al. (2016)	18–29	34	Musicians	Non-musicians	EF
Lesiuk (2015)	9–11	71	EF deficits	Average EF scores	Musical perception
Moradzadeh et al. (2015)	no data	153	Bilingual musicians, monolingual musicians	Bilingual non-musicians, monolingual non-musicians	EF
Schellenberg (2011)	9–12	106	Musicians	Non-musicians	EF
Zuk et al. (2014) [adults]	18–35	30	Musicians	Non-musicians	EF
Zuk et al. (2014) [children]	9–12	27	Musicians	Non-musicians	EF

The most frequently used assessments are the digit span and the trail making test (TMT). Four out of seven studies apply the digit span from the WAIS-IV intelligence scale, which examines the capacity of working memory by asking the participant to repeat a series of digits either in the same order (digit span forward) or backwards (digit span backward). The TMT, which is used by three out of seven studies, is generally applied to measure task switching but seems to measure working memory ability to a greater extent (Moradzadeh et al., 2015; Salthouse, 2011). It requires the subject to connect numbers and letters in the correct order. Also, one of the measures of the behaviuor rating inventory of EF (BRIEF) reveals the capacity of working memory which, additionally, seems to correlate with the spatial hearing task (Clayton et al., 2016).

The studies on children reveal significant results for working memory tasks. Lesiuk (2015) identifies working memory as the only independent predictor of duration and rhythm perception when comparing healthy children to those with EF deficits. Schellenberg (2011) mentions significant differences between the musically trained and the untrained children only on the digit span, and Zuk et al. (2014) calculate significant differences on the TMT, but also on processing speed as measured by the coding subtest of the WAIS-IV and verbal fluency.

When comparing the children and the adult population in Zuk et al. (2014), it seems that musical ability shows up differently on the EF profile between the age groups. While both have significantly higher scores on verbal fluency than their untrained peers, there is only a trend for processing speed in the adult group in contrast to significant differences in the child group. Additionally, musical adults outperform their controls in design fluency and digit span backward, which the children groups do not. The other studies on adults' groups do not match for the most part regarding testing methods. Clayton et al. (2016) and Zuk et al. (2014) both evaluate significant results on the digit span, indicating higher working memory capacities in individuals with musical expertise. Moradzadeh et al. (2015) test for task switching and dual task, which is not addressed by the other studies. Bialystok and DePape (2009) report significant differences between the groups only on the Simon arrows test for response speed, which is not affronted by the other studies. In general, differences between the groups with and without musical training are frequent within the correlation studies. The majority also addresses on

working memory capacity: Five out of seven studies report better working memory skills in the experimental groups (Table 2).

Table 2. Tests and results

Study	Test(s)	Results
Bialystok and DePape (2009)	Spatial span; trail making test A + B; Simon Arrows; auditory stroop	Monolinguals slower; groups differ on EF tasks; significant results only on Simon Arrows
Clayton et al. (2016)	Digit span backwards; colour-word interference; design fluency	Musicians showed better performance on measures of auditory working memory (Digit Span)
Lesiuk (2015)	BRIEF	Significant differences discriminating duration of tones and rhythm patterns; pitch and melodic perception are perceived similarly; working memory as only independent predictor of duration and rhythm perception
Moradzadeh et al. (2015)	Task switching; dual-task	Musical training improves efficiency in the ability to shift between mental sets; musicians outperform non-musicians on dual-task; no interaction between music and language; long-term musical training correlates with Task Switching and Dual-Task performance
Schellenberg (2011)	Digit Span; phonological fluency trials; sun-moon-stroop; tower of hanoi; Wisconsin card sorting	No differences between the musically trained and untrained groups; performance was slightly better for the trained group on each measure; significant differences only for digit span
Zuk et al. (2014) [adults]	Digit span; trail making; verbal fluency; colour-word interference; design fluency, coding	Enhanced performance on cognitive flexibility, working memory, and verbal fluency; significant results for verbal fluency, design fluency, digit Span (backward); trend for Coding
Zuk et al. (2014) [children]	Digit Span; trail making; verbal fluency; colour-word interference, coding	Enhanced performance on measures of verbal fluency and processing speed + activation in the brain (fMRI) in children; significant results for coding, verbal fluency, trail making test

3.2. Results for intervention studies

Within the *intervention studies*, the age groups consist of two groups of preschoolers (4–6 years), one of school children (8–12 years), two of elderly (60–85 years) and one study does not provide any information. Three studies are rather small with less than 35 participants, two have between 36 and 65 and one study assesses 265 individuals. Apart from one study, all involve only healthy people and all studies use control groups. The duration varies between two weeks and three years, with only one study lasting longer than one year. Three studies apply their activities daily, one three times, one twice a week and one administers the interventions at irregular intervals (Table 3).

In this review, instrumental lessons or combinations with them (three out of six) occur most frequently followed by free improvisation on percussion instruments (one out of six), a computer training program with music (one out of six) and music therapy (one out of six). The activities during the improvisation intervention, however, are similar to typical activities in a music therapy session. The instrumental instructions regard piano lessons in two cases. The combination of instrumental lessons and ensemble classes in one case provides additional socio-dynamic and motivational aspects, like organising and synchronising oneself in a musical and in a social context. Therefore, it might be difficult to understand, if changes in EFs are caused by music making or the teamwork within ensemble activity. Half of the studies compare their interventions to no alternative programme, one offers activities with Lego, one a computer training program without music and another lets the

controls rest. The resting time condition, however, might be very similar to the absence of any intervention.

The two studies with age groups over 60 years apply only piano lessons. The children's activities and control conditions are more different like: Improvisation, a computer program and free time. The groups with elderly participate in the respective programmes for at least four months, the time span of the children differs between four weeks and three years. Three studies apply their interventions on a daily basis (excluding weekends in two cases).

Two studies with child populations report better performances on the go/no-go tasks, indicating an increase in response inhibition. Most studies (five out of six) compare the effect of their interventions in healthy individuals, only one works on a population with cognitive deficits after traumatic brain injury (Table 3).

Table 3. Details on the samples

Groups	Age	*N*	Experimental condition	Control condition	Duration	Frequency
Bugos, Perlstein, Mccrae, Brophy and Bedenbaugh (2007)	60–85	31	Healthy elderly: piano lessons	Healthy elderly: no intervention	6 months	3x/week
Bugos and Demarie (2017)	4–9 and 5–8	34	Healthy children: percussion/improvisation	Healthy children: LEGO	6 weeks	2x/week
Holochwost et al. (2017)	8–12	265	Healthy children: lessons/ensemble	Healthy children: No intervention	3 years	2h/day (5x/week)
Moreno et al. (2011)	4–6	64	Healthy preschoolers: computer training program with music (listening)	Healthy preschoolers: computer training program with visual art	4 weeks	2x/day (5x/week)
Seinfeld, Figueroa, Ortiz-Gil, and Sanchez-Vives (2013)	60–84	29	Healthy elderly: Get piano lessons	Healthy elderly: No intervention	4 months	45min/day

The tests that report significant results on EF tasks are the digit symbols, TMT (A + B), the matching familiar figures test, the (day/night) Stroop, go/no-go, and Wisconsin card sorting task. Digit symbols, a WAIS-III subtest, evaluates processing speed. The TMT, as established by Moradzadeh et al. (2015) and Salthouse (2011), is an indicator for working memory. The matching familiar figures test measures reflection-impulsivity. The (day/night) Stroop and the go/no-go test for inhibitory control. The Wisconsin card sorting test measures mental flexibility and rule switching. The trend from the correlation studies (chapter 4) according to which the digit span and the TMT hint towards a correlation between working memory and musical ability cannot be confirmed in the intervention studies. In three studies that use the digit span, none reports significant results, but Bugos et al. (2007) describes a trend. The TMT performs slightly better: It delivers significant results in two of three studies and a trend in one. The Stroop tests are applied in three studies and deliver two significant results and one trend, indicating a gain in inhibitory control.

Inhibitory control improves significantly in three out of six cases, two of them contain child populations and the last child population shows a trend. However, this does not match with the studies with children among the correlation studies. Two out of three studies that use tests on working memory report significant gains, but in general the present studies apply less tests regarding it (Table 4).

Holochwost et al. (2017) is an exceptional study among the others, because of the complexity of its intervention (combination of instrumental lesson and ensemble activities) and its duration of three years, which allows to observe long-term effects. Inhibitory control and flexible attention improved after one year in the experimental group, however, the largest differences on EFs between the groups could be observed after two to three years, which indicates that some changes in EFs need several years of time to occur in formal testing. Better scoring on standardised tests and better grades in English and math are documented.

Table 4. Results

Studies	Test(s)	Results
Bugos et al. (2007)	Trail making tests; ward's seven subtests of WAIS III; information; digit span; arithmetic; similarities; picture completion; block design; digit symbol; the vocabulary; letter number sequencing subtests	Significant interaction on Digit Symbols; significant main effect for test time on TMT Card A; trend for the Digit Span Foward (WAIS-III)
Bugos and Demarie (2017)	Primary measures of music aptitude; day-night stroop; matching familiar figures test (MFFT).	Significant time by group interaction on the MFFT; only a main effect of time for the Day/Night Stroop Task (interference control).
Holochwost et al. (2017)	6 computerized tasks of EFs and STM taken from Psychology Experiment Building Language; 4 on inhibitory control/flexible attention; 2 others (Tower of London + Wisconsin Card Sorting Task) complex tasks on executive capacities across multiple domains	experimental group performed significantly better in Go/No-go, Stroop Test, Wisconsin Card Sorting Task (inhibitory control, flexible attention)
Moreno et al. (2011)	WPPSI-III; go/no-go task (EEG)	Significantly larger peak amplitudes in the no-go trials after musical training; sig. improvement in intelligence scores after musical training (only on the verbal test); verbal intelligence are positively correlated with changes in functional brain plasticity during an executive-function task
Seinfeld et al. (2013)	Block Design (WAIS-III); digit span; trail making test; symbol digit modalities test; stroop test; formal lexical task	Significant improvements after piano training in tests that measure attention and executive function (Stroop and a trend in TMT-A); sig. improvement in the exp. Group (pre-/post)
Thaut et al. (2009)	Digit Span; Trail Making Test B	Significant improvement on the TMT-B in mental flexibility in the experimental group; no

	improvement in attention functioning in neither group; improvement in executive function in experimental group; control group show decreases in measures of memory, positive affect, and sensation seeking

4. Discussion

Music making seems to have an effect on several aspects of EF, and all studies could report correlations between musical experience and EF (or musical intervention and EF respectively). The kind of EFs that show to be influenced, however, differ. Still there is a hint towards working memory: A significant gain is reported in several *correlation studies*, but not so much in the *intervention studies*. This could be caused by the fact that the *intervention studies* tested less for working memory. As pointed out by Schellenberg (2011) and Hargreaves and Aksentijevic (2011), the relationship between music and cognition is highly complex. It is therefore not possible to reduce one specific type of intervention to predict an increase in a specific EF. This is reflected in this paper, since music-based interventions and music lessons lead to an overall increase in some EFs, but not in all. This is in-line with previous research implying that working memory (a part of EFs) plays a part in musical skills (George & Coch, 2011), and that rhythm perception ability seems to be significantly related to auditory working memory and reading skills (Strait, Hornickel & Kraus, 2011). In fact, this paper confirms that working memory is frequently seen to improve under the influence of musical activity.

In 10 out of 12 articles, healthy individuals are used as subjects. The other two investigate individuals with EF deficits and those who suffered from traumatic brain injury. In order to explore the therapeutic effect of music and music therapy, it would be necessary to broaden the range of studies that work with populations having cognitive deficits – like people with autism spectrum disorders. Moreover, all interventions analysed in this work use musical interventions in which the subjects actively engage in the music making process. The majority of interventions is music educational. By applying this information on music therapy research, it might be concluded that active techniques seem to be the most promising when targeting EFs. In the same time, it does not seem to make a difference if instruments or singing is used, since singers and instrumentalists are documented to score similarly (Bialystok & DePape, 2009). Listening interventions – as part of a computer training – are addressed in only one study (Moreno et al., 2011). In consequence, it is not yet possible to make conclusions on the effect of receptive music therapeutical techniques – in which the patient would engage in listening and reflecting over music. Further research is needed to find out, how receptive musical approaches might influence EFs.

Research indicates that some of the benefits in EFs can be achieved after a longer period of time, namely after more than a year (Holochwost et al., 2017). Since there is yet only a few long-term researches reported in the literature, further research is needed. The school context offers in this case an enormous potential, because children and adolescents can participate in an environment with rather little fluctuation within the population: Even if individuals join or leave the school, the majority stays. In special education context, individuals with EF weaknesses like those with autism spectrum disorders can be observed for a longer period of time. In fact, music lessons or music therapy could be scheduled regularly providing a comparatively inexpensive and engaging possibility of research and cognitive improvement, and monitored on a regular basis.

Deficits in EF within populations on the autism spectrum are frequent, however, even though there is a general weakness on EF the fractionation into different subdomains does not seem possible (Demetriou et al., 2017). This might indicate that individuals on the spectrum have individual weaknesses and strengths regarding EFs. In fact, both typical and atypical development of EFs in people with autism spectrum disorders have been reported (Luna, Doll, Hegedus, Minshew & Sweeney, 2007). Additionally, there is research indicating that EFs can be improved in intervention

studies on subjects on the spectrum (Kenworthy et al., 2014). It is probable that future music therapy research seeking an effect on EF in populations with autism, will have to face personally unique changes in EFs when applying music therapy. Therefore, an individual approach and a broad battery of tests covering a large variety of EFs might be useful.

5. Conclusion and recommendations

This paper confirms that music interventions seem to have an effect on EFs. However, the nature of these effects, remains a subject for the upcoming research. Further research is also needed to gain a better understanding on the long-term effects of music making and consequently, for its potential in therapy and school contexts. Studies on the EF outcome of music interventions on populations with autism spectrum disorders are essential for future music therapy. This review confirms that music therapy might be fitted as an additional tool in special education, in order to train EFs, and to help individuals with EF deficits in their scholastic career.

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