Learning a musical instrument can benefit a child with special educational needs

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Abstract

This study explores outcomes related to musical learning in a child with complex special educational needs. CB is a boy who was eight-years-old at the start of the study, and who was diagnosed with co-morbid Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder, Sensory Processing Difficulties, Dyslexia and Dyspraxia during the study. He was evaluated on a battery of developmental measures before and after one year of music learning. At pretesting CB obtained a high musical aptitude score and an average IQ score. However, his scores on tests measuring motor abilities, executive function, and social-emotional skills were low. Post-testing revealed improvements in CB's fluid intelligence and motor skills, and whilst teacher and parent reports suggested a decline in his social-emotional functioning, his musical progress was good. The results are discussed in the context of impairments in developmental disorders, the importance of flexible teaching approaches and family support for music learning during childhood.

Introduction

The cognitive, behavioural and social-emotional benefits of arts-based learning in childhood have long been a source of interest to researchers and those working in politics and public policy (Fiske, 1999; Henley, 2011, 2016; Hetland & Winner, 2004). At the same time, music perception and production has been of particular interest to cognitive neuroscientists, and the application of this knowledge has produced new insights into music and the mind for typically developing children as well as those with special needs (Heaton, 2009; Schlaug, Norton, Overy & Winner, 2005; Thaut, 2008). Quantitative methods have been used to evaluate the benefits of arts-based music learning programmes, and these studies have reported overall gains in a range of cognitive, behavioural and social-emotional skills (Forgeard, Winner, Norton & Schlaug, 2008; Hallam, 2010; Overy, 2003; Rose, Jones Bartoli & Heaton, 2017). Some research has focused on the notion of near transfer effects associated with skill specific training, such motor abilities (Costa-Giami, 2005; Forgeard et al., 2008) and auditory memory (Ho, Cheung & Chan, 2003; Rickard et al., 2010). Other studies have considered the idea of the far transfer of musical learning, such as improvements in reading (Butzlaff, 2000), non-verbal reasoning (Vaughn, 2000; Hyde et al., 2009), intelligence (Schellenberg, 2004) and how listening can enhance spatial skills (Harland, 2000; Leng & Shaw, 1991). Furthermore, Karkou and Glasman (2004) suggest that music learning within the school environment promotes social inclusion and emotional wellbeing. For example, Rickard and colleagues (2013) provide evidence of the positive impact of musical learning on self-esteem. Overall, research suggests that musical learning promotes pro-social behaviours and has a positive impact on wellbeing (Croom, 2015; Daykin, De Viggiani, Pilkington, & Moriarty, 2012; Harland et al., 2000; Kirschner & Tomasello, 2010; Moore, Burland & Davidson, 2003).

Neuroimaging studies of musical training have identified long term structural brain differences between musicians and non-musically trained people (James et al., 2014). In children, specifically, Schlaug et al., (2005) reported enhanced activation of the bilateral temporal lobes and superior temporal gyri during rhythmic and melodic discrimination tasks in five to seven-year-olds after one year of musical training. Re-testing at 15 months revealed changes in the motor cortex, the corpus callosum, and the right Heschl's gyrus in musically trained, compared to age matched control children who had not undergone musical training.

Whilst group studies provide a strong case for the efficacy of music learning during childhood, understanding variability in responses to musical interventions is particularly important when considering children with special educational needs. Such children often achieve statistically outlying test scores, for example on measures of cognitive ability, which result in their exclusion from group studies. This is unfortunate given the promising results from studies specifically targeting participants diagnosed with learning difficulties associated with developmental disorders. For example, music-based interventions have been shown to improve spelling in children with Dyslexia, and to increase social responsiveness in children with Autism Spectrum Disorder (ASD; Finnigan & Starr, 2010; Kern & Aldridge, 2006; Overy, 2003). Developmental disorders frequently show overlap in terms of diagnosis and impairment, and this may be further complicated by symptoms of developmental delay (e.g. sensory, memory, cognitive, motor and language difficulties). For example, low motor competency is characteristic in both ASD and Attention Deficit Hyperactivity Disorder (ADHD; Rasmussen & Gillerg, 2000; Geuze et al., 2001). Though such difficulties may impact on musical learning, the development of motor skills using musical intervention has been successful (Montello & Coons, 1998; Schoemaker et al., 2003). For example, in Neurologic Music Therapy, Thaut and colleagues (1999; 2005;

2015) have shown how rhythmic entrainment can be utilised optimize motor planning and execution (alongside applications to cognitive, speech and language rehabilitation).

The provision of musical training for children with complex learning and social-emotional needs presents unique challenges for music teachers trained to work with typically developing children in mainstream schooling. Though music lessons may not be thought of as therapeutic per se, the notion of transfer effects of skill specific learning resonates in the educational context. A potential strength of studies carried out into music learning in individuals with special educational needs is that the participant's profiles of cognitive and/or behavioural difficulties may be well understood and this can inform the development of appropriate testing methods and music teaching and/or intervention programmes. Therefore, the overarching aim of this case study is to provide new insights into the efficacy of musical instrument lessons for children with special educational needs in mainstream education. This case study forms part of a larger project investigating music learning in typically developing children and group data from standardized tests used in the study will be presented for comparison purposes where relevant.

Method

Participants

The subject of the case study (CB), together with a cohort of typically developing seven to nine-year-old children (N = 38) participated in a musical learning study carried out by the authors (Rose et al., 2017). Although CB did not have a statement of special educational needs at the point of recruitment, pre-testing revealed that his scores on standardized psychological tests varied as much as three standard deviations from the group mean. Whilst these outlying scores meant that CB's data could not be included in the analysis for the group study, his musical aptitude was good and his home environment was conducive to music learning. In the following section, we provide a characterization of CB, including quantitative and qualitative data, to enable a full understanding of his condition.

Characterisation of CB

CB is a left-handed white male student who attended a mainstream state primary school in an urban working class area in the midlands of England. He was eight years old at the start of the study, which lasted one academic year (nine months).

According to his mother, CB had been given a preliminary diagnosis of Asperger syndrome at four years old, and during the period of the study he was further evaluated by a clinical psychologist. This evaluation resulted in a formal diagnosis of Autism Spectrum disorder (ASD), Attention Deficit Hyperactive Disorder (ADHD) and Visual and Auditory Processing Disorder. The psychologist also reported that CB showed patterns of cognitive impairment characteristic in Dyslexia and Dyspraxia[1]. It is difficult to draw firm conclusions about how CBs developmental difficulties might impact on his music learning on the basis of this assessment. We therefore provide a précis of the characteristics of these different diagnoses according to the Diagnostic and Statistical Manual (fifth edition, DSM-V; APA, 2013).

ASD is a neurodevelopmental disorder diagnosed on the basis of social communication difficulties and repetitive and/or restrictive patterns of behaviour, activities or interests. Individuals with ADHD demonstrate persistent patterns of inattention and/or hyperactivity-impulsivity that interfere with functioning in the home or school. Visual and Auditory Processing Disorders do not directly result from observable impairments in

[1] Although more usually this would be Developmental Coordination Disorder (DCD), we report the term used by CB's mother.

hearing or sight, but they do disrupt the individuals' ability to process visual information to discriminate and localize sounds. Dyslexia is categorized as a language processing difficulty that impacts on reading and writing, and Dyspraxia (i.e. DCD) is characterised by impairments in planning and coordinating motor movements. It is clear from CB's complex diagnosis that he experiences wide ranging difficulties that are likely to impact on social-emotional development and learning across multiple domains.

At the beginning of the study, CB's teachers and parent expressed their belief that music lessons could help him focus his attention, improve his communication skills and provide an artistic outlet for his 'feelings'. It was clear that CB would receive significant support from the adults in his life to enable this. In the initial data-gathering phase, parents were asked questions about their attitude to music and their own level of musical engagement. The rationale for this was that parental involvement is an important factor in children's musical enrichment (Davidson, Howe, Moore, & Sloboda, 1996; Hargreaves, 1986). CB's mother reported that she played piano and guitar, and sang; writing, "Music plays an important part of our daily lives". When asked about how important it was for her child to have a musical education, she described it as 'essential'. Prior to learning the tenor horn, CB had spent less than one hour each week engaging in music at school. However, he spent up to three hours each week in self-motivated musical engagement at home (dancing with mother and singing with siblings), and CB's mother reported that this increased over the period of the study. At the start and end of the study, CB's mother completed questionnaires about CB's activities and behaviours at home, his form tutor about his school behaviours and his horn tutor provided a weekly account of his music lessons. CB and the other children completed a battery of measures designed to offer a comprehensive perspective of the concomitant development of his cognitive, behavioural and social-emotional development in the first year of his musical learning. All measures were administered to the children individually except the PMMA which was administered to the children in small groups. A description of these tests, and the reason for their inclusion in this case study are detailed in the following section.

Measures

As musical aptitude is likely to influence motivation, and potentially increase the success of the music intervention, we used Gordon's Primary Measure of Musical Aptitude (PMMA; Gordon, 1986) to measure CB's basic musical aptitude. In the test forty pairs of musical phrases are presented in a same/different paradigm to test tonal and rhythmic skills. For the tonal tests, these differ in pitch contour. For the rhythm test, stimuli are presented on the same pitch but differ in note duration. The Beery (2004) test of visual-motor integration was presented as a distractor task between tonal and rhythmic tests[2]. The Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999) was used to measure CB's intelligence. The WASI includes Matrix Reasoning, Block Design, Vocabulary and Similarities subtests, which combine to provide a Full Scale IQ score. Performance IQ encompasses Matrix Reasoning and Block Design subtests and Verbal IQ encompasses Vocabulary and Similarities subtests. The Children's Memory Scale (CMS; Cohen, 1997) provides measures of short-term, long-term and working memory, and executive function. In CB's assessment, Word List Learning and Word List Recall were taken from Domain A, which measure auditory short-term memory and long term memory consolidation respectively. Digit Span Forwards (DSF) and Digit Span Backwards (DSB) and Sequences were taken from Domain C, which measures attention and concentration in children. DSF is believed to measure short-term memory whilst DSB loads more heavily

[2] The results of this test are not reported here as adherence to instructions in the group administration of the test was not reliable.

onto working memory (St. Clair-Thompson, 2010; St. Clair-Thompson & Allen, 2013). Fine and gross motor abilities were assessed using the age appropriate tasks in the Movement Assessment Battery for Children (Movement ABC-2; Henderson, Sugden & Barnett, 2007). The Behavioural Assessment System for Children (BASC-2; Reynolds & Kamphaus, 2004) assessed socio-emotional wellbeing from the perspective of the parent and for teacher using 150-170 item questionnaires[3] with items grouped into clinical and adaptive scales. Ethical permission to carry out the study was granted by the Research Ethics Committee at Goldsmiths, University of London.

Results

Statistical Analyses

An aim of the study was to identify differences occurring during the period the of the musical intervention between test scores at time 1 and time 2. This difference was divided by the standard deviation for the group study mean to produce a measure of effect size (Cohen's d). With the exception of the WASI (where IQ and T Scores are provided in line with other studies), Table 1 provides data as percentiles (as well as Cohen's d) to enable comparison between CB's and the group study results[4] for the musically trained participants from Rose et al., (2017). In the following section values of Cohen's d greater than 1 were described as large.

[3] For BASC-2 parent report, the clinical scales of Anxiety, Atypicality and Withdrawal are missing due difficulties between questions spanning over the age period leading to issues of internal validity.
[4] Alpha p value was set at .05 but adjusted for multiple comparisons to avoid Type 1 errors.

Table 1. Case study results in the context of the group study[1]

	Time 1		Time 2		Effect Size (Cohen's d)	
Measure	CB	Group	CB	Group	CB	Group
Primary Measure of Musical Aptitude (PMMA; % ile)						
Rhythm	62	58.82	91	72.72	1.24	ns
Tonal	74	64	66	74	ns	ns
Weschler Abbreviated Scale of Intelligence (WASI) Full Scale IQ	103	108.84	112	115.79	ns	ns
Sub-tests (T Scores)						
Matrix Reasoning	45	51.79	58	56.42	1.31	0.6
Block Design	46	51.68	42	52.74	ns	ns
Vocabulary	52	52.95	58	60.42	ns	ns
Similarities	64	61.58	71	61.95	ns	ns
Children's Memory Scale (CMS; % ile)						
Word List Learning (Auditory short-term memory)	25	47.97	63	56.47	ns	ns
Word List Recall (Auditory long-term memory)	75	64.58	37	66.44	ns	ns
Digit Span Forwards (Auditory short-term memory)	16	59.28	2	70.37	ns	ns
Digit Span Backwards (Auditory working memory)	37	43.39	50	54.89	ns	ns
Sequences (Executive function)	9	55.31	9	75	ns	0.8
Movement Assessment Battery for Children (Movement ABC-2; % ile)						
Aiming and Catching	16	39.65	50	51.33	0.94	0.8
Manual Dexterity	16	37.78	50	42.34	1.39	ns
Balance	63	55.78	50	62.67	ns	ns
Behavioural Assessment System for Children (BASC; % ile)						
Parent						
Attention Problems	81	51.47	95	51.6	3.14	ns
Hyperactivity	89	47.6	98	49.6	0.97	ns
Form Teacher						
Social Skills	49	51.67	17	55.22	-3.8	ns
Aggression	58	43.33	96	44.67	3.01	ns
Anxiety	59	42.22	94	46.89	2.67	ns
Attention Problems	51	44.67	89	41.11	5.73	ns
Conduct Problems	60	43.78	96	44.33	4.24	ns
Depression	84	44.44	98	44.89	1.29	ns
Hyperactivity	75	43	99	45.33	3.38	ns
Withdrawal	62	45.33	87	43.56	2.8	ns

[1] Rose et al., (2017).

Primary Measure of Musical Aptitude (PMMA; Gordon, 1986)

As figure 1 shows, CB's overall musical aptitude score was above average (65th percentile) and higher than the group mean score (61st percentile). CB's Rhythm score showed a large increase between time 1 and 2, mirroring the group result (see Table 1), but remained stable for the Tonal component.

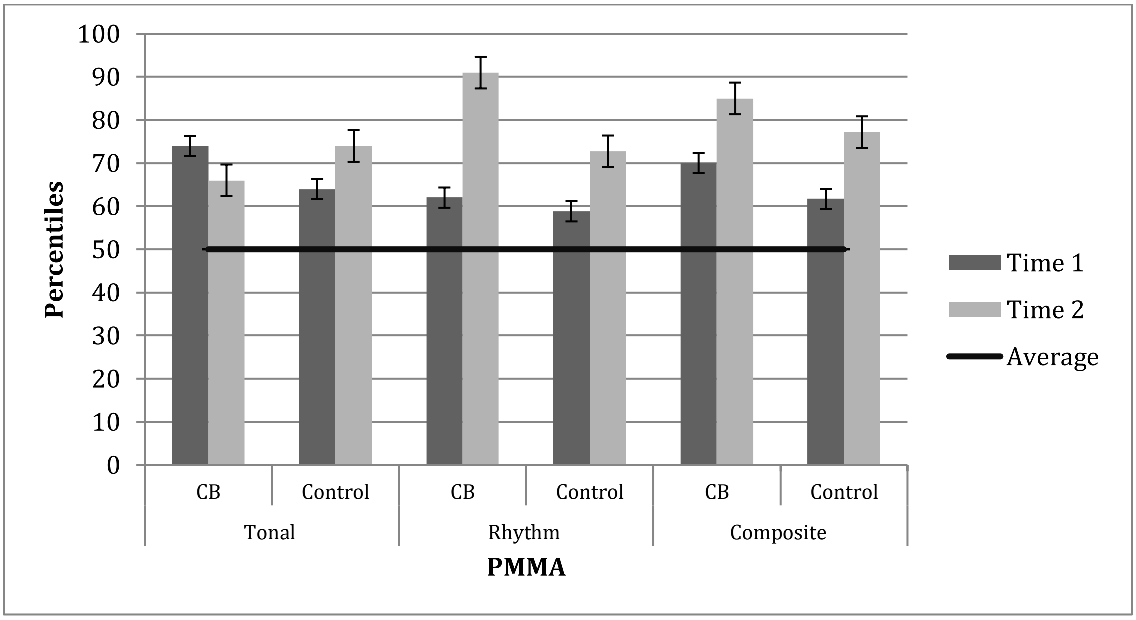

Figure 1. Primary Measure of Musical Aptitude (PMMA) comparison between CB and group over time

Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999)

CB achieved average intelligence scores on the WASI, with a Full Scale IQ score of 103 at time 1 and 112 at time 2. Though this change was positive, it was less than 1 SD. However, as can be seen in Table 1, analysis of the sub-test scores revealed a large increase in performance on the Matrix Reasoning test. This improvement in non-verbal reasoning also mirrors the statistically significant improvement reported in the group study, of which this case study forms a part (Rose et al., 2017).

Children's Memory Scale (CMS; Cohen, 1997)

As figure 2 shows, CB's pattern of performance on the subtests of the CMS was very uneven at time 1. For example, he scored in the 75th percentile on Word List Recall, suggesting intact long-term memory but in the 9th percentile on the Sequences subtest, suggesting impaired executive function. Similarly, scores on subtests measuring auditory short-term memory were low. For example, he scored in the 25th percentile on the Word List Learning test and in the 16th percentile on the Forward Digit Span test. However, CB's scores on the backward digit span task were average for his age, and it is difficult to see how working memory (assessed by Backward Digit Span) could be intact when auditory short-term memory (assessed by Forward Digit Span and Word List Learning) was impaired. The assessment at time 2 did not suggest marked changes in any of CB's memory subtest scores (see Table1). This pattern contrasted with the results from the group study where a significant increase on the Sequences subtest, measuring executive function, was observed (Rose et al., 2017)

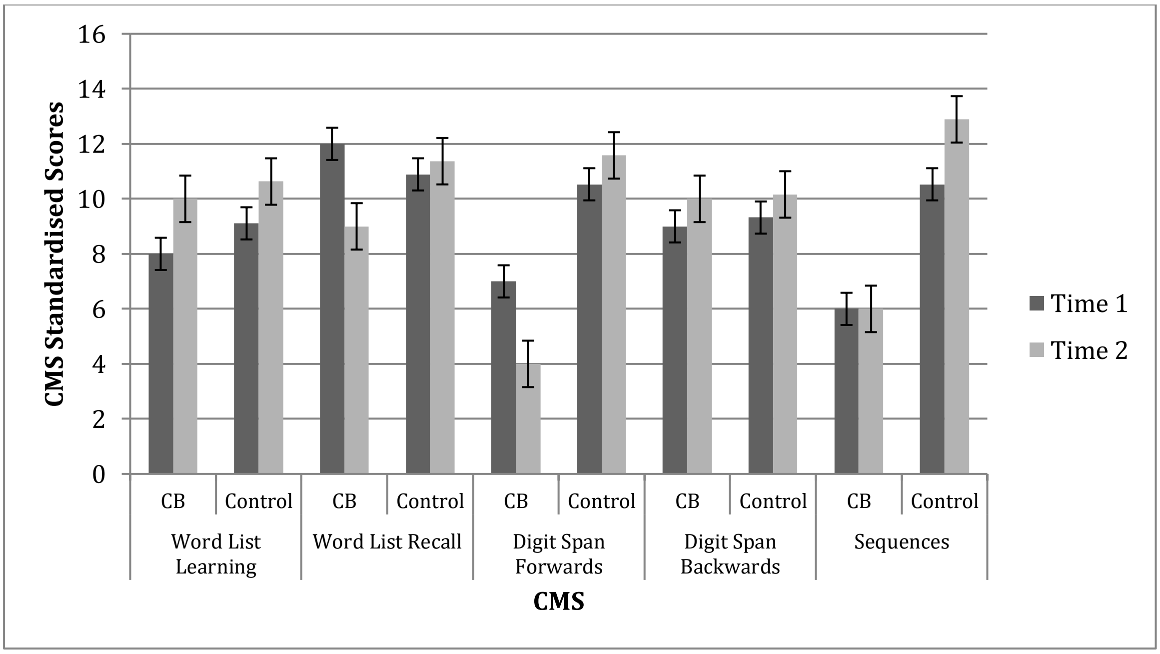

Figure 2. Children's Memory Scale (CMS) comparison between CB and group over time

Movement Assessment Battery for Children (Movement ABC-2; Henderson, Sugden & Barnett, 2007)

As can be seen in figure 3, CB's movement skills were below average for all components except Balance at time 1. Large changes were observed for CB at time 2 with an increase from the 16th to the 50th percentile for both the Aiming and Catching and Manual Dexterity components. Scores on the Balance subtest did not change between time 1 and 2. To provide context with the group study, a statistically significant change was observed for Aiming and Catching component only (see Table 1).

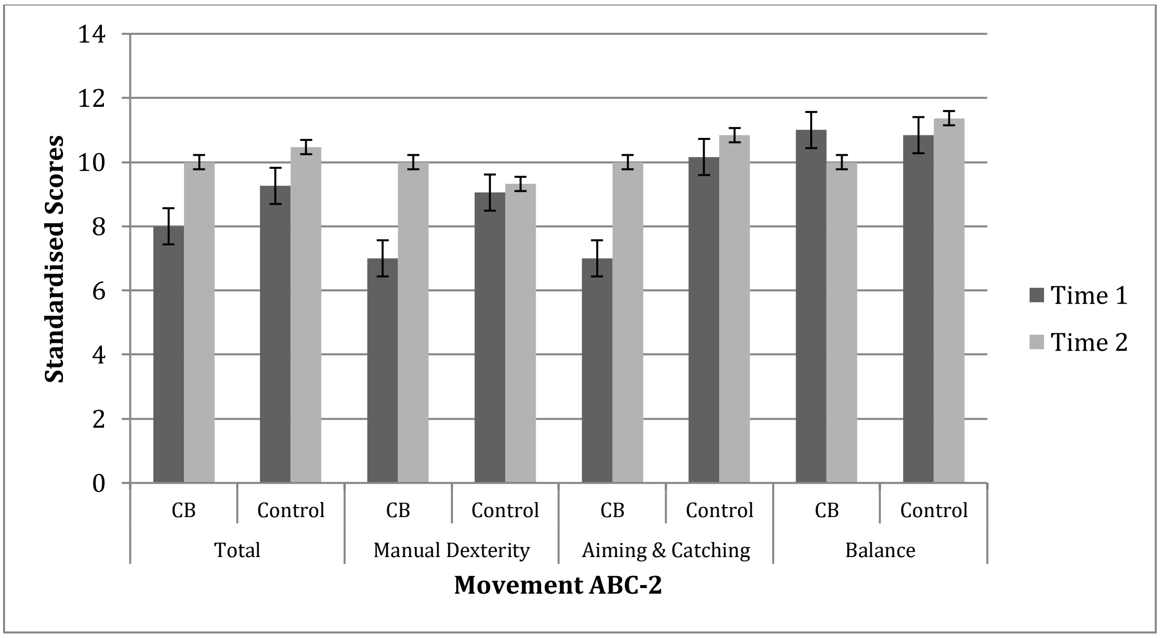

Figure 3. Movement Assessment Battery for Children (Movement ABC-2) comparison between CB and group over time

Behavioural Assessment System for Children (BASC; Reynolds & Kamphaus, 2004)

As CB was diagnosed with ASD and ADHD, data from the scales that measure social skills, attention problems and hyperactivity were of particular interest. In the pretest CB's mother and teacher reported levels of Aggression, Conduct problems, Attention problems, Hyperactivity and Depression that are flagged as a cause for concern in the BASC manual. The pattern of test scores at time 2 showed considerable differences across teacher and teacher reports, possibly reflecting variability in CB's functioning across home and school environments. At time 2 testing CB's mother reported large increases in the clinical scales of Attentional Problems and Hyperactivity. His form teacher reported a large decrease in the adaptive scale of Social Skills (suggesting worsening socialization skills) and large increases in the clinical scales of Aggression, Anxiety, Attention Problems, Conduct Problems, Depression, Hyperactivity and Withdrawal. These changes suggest that CBs learning and behavioural difficulties showed considerable deteriation over the year, especially considering they were in marked contrast to the group scores (see Table 1),

Summary of Music Tutor Notes

Table 2 – Themes and summary of music tutor notes

Themes	Frequency of Comment (n)	Summary content of comments
Positive progress in musical learning	19	Could play/read notes and songs, could play higher, improvised on C and D, answered questions about crotchets and minims, could play Pease Pudding Hot with everyone else
Motivation to learn	9	Seems to be enjoying it, played a solo in school orchestra club, irregular practice, learned new notes in preparation for school band, practices band parts and solo for school music festival
Issue relating to motor skills and technique	3	Difficulties with tonguing technique, uncoordinated and clumsy
Cognitive issues with musical learning	5	Difficulty remembering note values, good at remembering individual notes but not when in a tune (i.e. difficulty with pitches when on stave), guessed at band music

The results from the standardized assessments revealed strong musical potential and average intelligence that co-occurred alongside difficulties in executive, motor, memory and social-emotional skills at time 1. CB’s pattern of performance on the assessments at time 2 showed some areas of improvement (motor skills and fluid intelligence), decline (executive function and social-emotional behaviours) and stability (some aspects of memory) over the period of the study. In the following section the impact of CB’s strengths and difficulties on his music learning will be explored. CB attended 26 half hour music lessons and the music tutor made extensive notes that are summarized in table 2[5]. In the lessons the music tutor focused on instrumental technique (embouchure formation,

[5] Full account provided in Rose, D. (2016).

tonguing, fingering), listening skills, practice skills, music reading (beats and notes) as well as improvisation.

Whilst many of these behaviours may be observed in typically developing children in their first year of learning a musical instrument, some behaviours appear to reflect CBs behavioural and learning difficulties. The formation of embouchure, tonguing and fingering rely of the recruitment of motor skills and CB’s difficulties in mastering these techniques was unsurprising given his diagnosis and pretest results in the Movement ABC-2. The development of practice skills requires considerable organization and CB’s poor performance on the test of executive function suggested a further area of potential difficulty. CB’s horn tutor mentioned that CB’s practice was inconsistent, and he often forgot his music book and arrived late for lessons, occasionally missing sessions altogether. Similarly, CB’s test results suggested some memory impairment and the tutor’s notes alluded to problems with aspects of musical memory. CB’s horn tutor recorded that within lessons, he needed to remind CB which note was which. He also noted that CB misbehaved and “messed around”. However, CB was motivated to learn and did progress during the year. His horn tutor described a number of adaptations made to accommodate CB’s developmental difficulties, capitalizing on his motivation, musical aptitude and intelligence. This collaborative approach is likely to have contributed to his success. Examples of adaptations over a three-week period, and are described below.

> **Week 9** – “I met with his Mum - she told me that he has dyspraxia, and all sorts of other things. He likes colours, so we agreed on getting [him] to colour code his notes.”

> **Week 10** – "Got him to choose colours e.g. red for all C's, green for all D's etc. He drew coloured circles around each note - seemed to really enjoy it, and it helped with playing."
>
> **Week 11** – "He could play Hot Cross Buns today, looking at the colour coded notes. It seems to work."

The music tutor appeared to demonstrate flexibility, creativity and commitment in the lessons and this facilitated CB's motivation to learn the tenor horn. CB went on to join the school orchestra and played a solo in the end of year school music festival.

Discussion

This section draws the qualitative and quantitative results together with the diagnosis to provide new insights into how learning a musical instrument in a mainstream school can be of benefit to a child with complex learning and behavioural problems.

At time 1, standardized tests provided a profile of an eight-year-old child (CB) that suggested some apparent strengths (such as his musical aptitude and intelligence) as well as potential areas of learning and behavioural difficulties (such as executive function and inhibition). These results were mostly congruent with the complex diagnoses CB's mother reported receiving; although whilst such difficulties may be observed in children with ADHD, Auditory and Visual Processing Difficulties, Dyslexia and Dyspraxia, they are also observed in some children with ASD (Gargaro et al., 2011; Matson, Matson and Beighley, 2011; Piek & Dyck, 2004). Deficits in attention, motor control and perception (referred to as DAMP; Hellgren et al., 1994) have even been suggested as more clinically relevant than the concept of ADHD (Kadesjö & Gillberg, 1998). However, the pattern of social-emotional difficulties reported at time 1 are most strongly consistent with a diagnosis of ASD and appeared to confirm CB's preliminary diagnosis of Asperger Syndrome at 4 years old. Though these difficulties might have impacted upon his musical learning abilities, the aim of the mother and school in providing musical instrument lessons for CB was to improve his focus and attention skills whilst also finding an artistic outlet for his emotions. This idea is suggestive of the notion of transfer effects from musical learning. Testing at time 2 showed a diverging pattern of change which helps us understand how CB's condition impacted positively and negatively upon his musical learning, and potentially vice versa. To begin with we discuss the concept of near transfer effects in terms of musical aptitude and motor skills in relation to CB's diagnosis.

Dyslexia and Dyspraxia for example are disorders that have been associated with deficits in rhythmic and motor abilities (Dellatolas et al., 2009; Goswami et al., 2002), for which metacognitive and musical interventions focusing on rhythm have been shown to be of benefit to children (Hulme & Snowling, 2009; Overy, 2000; Sugden, 2007). This evidence suggests a link between the measure of motor abilities (the Movement ABC-2) to the test of musical aptitude (the PMMA). In the group study (Rose et al., 2017), these two measures were significantly correlated. Here we reported that CB had above average musical aptitude according to the PMMA and increased his Rhythm score on this as well as his motor abilities for Manual Dexterity and the Aiming and Catching components the Movement ABC-2 over time. The music tutor contributed important qualitative evidence noting early on that CB was 'uncoordinated' and was having difficulties tonguing. However, this aspect of his learning was not mentioned later in the year suggesting those problems were less noticeable as the year progressed, reflecting the positive change evident in the Movement ABC-2.

In relation to his musical abilities, CB's score on the Rhythm component of the PMMA increased from the 62nd to the 91st percentile over time. This suggests that CB appeared not only to be above average but had an enhanced musical learning trajectory. As the underlying fundamental problem of Dyslexia and Dyspraxia may be related to temporal processing, it could be that the combination of, for example learning to count time for the crotchets and minims, with physical manifestations (such as copying, blowing, tapping and fingering) could have supported this aspect of CB's development as suggested by other studies (Forgeard et al., 2008; Huss et al., 2011; Overy & Molnar-Szakacs, 2009). In this context, (i.e. taken with the group study results) these findings suggest the musical training was having a positive impact on CB's fine and gross motor skills by improving his understanding of the relationship between force, time and space and his own control over velocity within these concepts.

Musical training has also been associated with positive changes in cognitive measures, which have been suggested as far transfer effects of musical learning, such as reading and spelling (Butzlaff, 2000; Overy, 2003) and non-verbal reasoning (Vaughn, 2000; Hyde et al., 2009). CB had average IQ at time 1, a result which is in line with research by Charman and colleagues (2010) reporting that 55% of children with ASD obtain IQ scores that are in the normal range. CB's overall IQ increased from 103 to 112 (within confidence intervals, as was the group finding). However, CB also showed a large increase on the Matrix Reasoning subtest of the WASI (also in line with the group study, Rose et al., 2017). The Matrix Reasoning sub-test assesses pattern detection, reasoning and problem-solving in fluid intelligence (Wechsler, 2003).

It seems likely that a combination of CB's dyslexia, visual processing and executive functioning difficulties impeded his ability to read the notes on the stave. However, we know from the horn tutor's notes that CB was keen to engage in finding a solution to this difficulty, and together they identified a colour coding scheme to help CB understand the musical notation. As Matrix Reasoning is essentially a pattern matching task, the positive result of this sub-test of the WASI suggests that CB may have applied his problem-solving skills to help him overcome this difficulty. Together these results suggest some benefits of musical learning in terms of transfer effects, but it is important to acknowledge that these changes occurred within a supportive environment. The interaction between horn tutor, who was sensitive to the students' individual needs, combined with the opportunity provided by the supportive school, and a musically engaging home-life, afforded the syzygistic alignment of environments that supports musical development in children (McPherson, Davidson & Faulkner, 2012).

That we see evidence of CB making gains on cognitive and motor skills in the same way as the typically developing children is remarkable in the context of his diagnosis, and potentially critical for CB's self-efficacy (Dweck, 1986). However, in contrast to those changes, CB's scores on social-emotional measures did not improve over the course of the project. The BASC assesses clinical and adaptive scales of social-emotional wellbeing in children. The parent and teacher reports showed some disparity between home and school, but in general high levels of Depression, Aggression and Conduct Problems. Children with co-morbid developmental disorders have been shown to score highly on measures of depression and anxiety (Ghaziuddin & Greden, 1998). Simonoff and colleagues (2008) suggest 70% of children with ASD have at least one co-occurring disorder, and 41% have two or more. The most common of these are social anxiety disorder (29.2%) and ADHD (28.2%).

CB was aware of his diagnosis and conscious of his learning difficulties and behavioural problems. These results suggest that some concurrent emotional difficulties may have been impacted on CB's learning and behaviours. Further observations support this suggestion. For example, when CB was repeating musical phases out loud during the administration of the PMMA, he was also able to secure popularity by gaining laughs from his peers. Though this behaviour in itself is not necessarily symptomatic of his developmental difficulties, it suggests that CB had acquired some useful strategies to create some emotional insulation that protected him in an environment which he found psychologically challenging. The horn tutor noted these behaviours too (i.e. using charisma to deflect focus away from his own uncertainty of the task). Elliott (1993) suggests that musical learning provides a goal-directed pleasurable reward system, and through this, musicians acquire a sense of the autotelic value of practice. For CB, it was critical that the horn tutor was motivated to help him overcome his difficulties. He established a good one-to-one relationship and adapted his teaching techniques to accommodate CB’s learning problems. Additionally, the school also put systematic behavioural and organizational boundaries in place. Weekly lessons could not be re-arranged, practice was expected, and specific goals continued to provide motivation for CB who wanted to perform with the school band in the end of year music festival.

McPherson and colleagues (2012) suggest the next stage of musical development encompasses a process of transactional regulation, referring to Sameroff’s model (2009) suggesting a transition from externally guided learning, to self-regulation. The parent and teacher reports from BASC help us understand how difficult this transitional stage must be for a child with complex learning and behavioural problems, and how the structures embodied in musical learning might enable him to navigate the social-emotional terrain. Studies have shown students generally perceive musical learning to be beneficial to their wellbeing (Kokotsaki & Hallam, 2007). Although CB’s progress may have been slower than typically developing children of his age, he succeeded in completing the course of lessons, joined the school band and played a solo in the end of year festival.

Finally, the combination of measures in this case study also provides other potential insights into musical learning for children with special educational needs, that may not otherwise have been apparent. For example, the PMMA is a test designed to specifically measure “the potential for musical achievement” in children (Gordon, 1981, p. 3). This is based on Gordon’s notion of ‘audiation’, which could be described as the ability the endogenously generate sounds. The results from this standardized musical aptitude test showed that CB had considerable musical potential, and this is consistent with findings from experimental studies investigating intact or enhanced perception of melody and rhythm in children with ASD (Heaton, 2009). The test is essentially an auditory discrimination task, reliant to some extent on auditory short-term memory. The horn tutor notes show that CB seemed to rely on learning by ear, but also that he was sensitive to sounds. These observations may be related as children with ASD can suffer from mild to moderate hearing loss and/or hyperacusis and/or difficulties with phonological processing (Rosenhall et al., 1999). CB’s diagnosis did include auditory sensory processing difficulties. However, his scores on the PMMA suggest this was not a problem related to music. Stuides have shown that children with developmental disorders may rely more on tonality than typically developing children (Don, Schellenberg & Rourke, 1999; Peretz & Hyde, 2003). Returning to the horn tutor’s observations, he believed that CB was reliant on learning by ear because he was having difficulties in remembering. Congruent with this observation, we noted that during administration of the PMMA tests, CB was asked several times not to repeat the phrases out loud. Children with ASD often repeat sounds (echolalia, Koegel & Koegel, 2006). CB seemed to use this strategy to work out whether the musical phrase was the same, or different, though it also had the secondary gain of making his peers laugh (much to CB’s enjoyment of this disruption). Though we know from CB’s performance on the CMS memory task that his long-term memory appeared intact, his performance on the short-term memory tests was uneven. As musical training has been associated with increased performance in verbal memory (Ho, Cheung & Chan,

2003) we tentatively suggest that the reported strategy (of repeating the sounds) would help CB hold the musical phrases in his phonological loop (Baddeley, 1992; Klingberg et al., 2002; Lee et al., 2007). This could explain the disparity between short-term and working memory evident in the forward and backward digit span test of the CMS results (see figure 2). However, we acknowledge that CB's performance on the Sequences test showed a stable deficit in executive function and it is possible that difficulties in attending associated with ASD, and the related difficulties associated with his complex diagnosis effected these scores (O'Hearn, Asato, Ordaz & Luna, 2008).

Limitations

Though this case study presents novel data regarding individual differences in comparison to group statistics, it is important to note that developmental trajectories may differ between the children. In particular, poor performance on measures of motor ability may be predicted developmental delay (Allerton, Welch & Emerson, 2011; Dewey et al., 2002; Hinckson & Curtis, 2013). With the co-morbid diagnosis including motor deficits and ADHD at his particular age, there is evidence to suggest that these conditions may be particularly significant for males (Pitcher, Piek & Hay, 2003). Other issues pertaining to generalizability concerning measurement error due maturation and regression to the mean should also be noted (Feinstein et al., 2015). However, by comparing this individual with the group study by Rose and collegues (2017), it is possible to demonstrate the magnitude of observed changes within an appropriate context.

Conclusion

The mixed methods approach of this case study has provided a deeper understanding of how a child in with complex learning and behavioural disorders in a mainstream school can benefit by learning a musical instrument, specifically for motor skills and fluid intelligence. For CB, a reliance on learning by ear was a necessary adaptation. History is not without examples of great musicians such as Louis Armstrong overcoming adversity through learning by ear, and by immersing themselves in the supportive structures of the musical world (Sloboda, 1991). We suggest that because CB was invested in his own identity as a horn player (Hargreaves & Lamont, 2017), this, together with the supportive context he was able to learn in, provided the motivation to overcome some of the difficulties he faced. CB is still playing the tenor horn.

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Addition to Author Note

The ideas and data in this article formed part of the first author's doctoral thesis*. Preliminary data was disseminated as a poster in November 2016 at the Royal

Society of Medicine Professionals conference on ‘Examining the utility of music interventions for children with learning disabilities’. Poster title: *A mixed-methods case study of primary-age children, with and without learning difficulties, learning musical instruments for the first time.*

*Rose, D. (2016). *On Becoming and Being a Musician: A Mixed Methods Study of Musicianship in Children and Adults.* (Doctoral dissertation). Goldsmiths, University of London. Retrieved from http://research.gold.ac.uk/19105/1/PSY_thesis_RoseD_2016.pdf).

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