

TENOR HORN CASE STUDY

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

Rose, D.,¹ Jones Bartoli, A.,² & Heaton, P.²

¹ Department of Psychology and Sport Sciences, University of Hertfordshire, U.K.

² Department of Psychology, Goldsmiths College, University of London, U.K.

Corresponding Author: d.rose3@herts.ac.uk, Tel +44 1707 284 546

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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.

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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).

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

78 Whilst group studies provide a strong case for the efficacy of music learning during
79 childhood, understanding variability in responses to musical interventions is particularly
80 important when considering children with special educational needs. Such children often
81 achieve statistically outlying test scores, for example on measures of cognitive ability,
82 which result in their exclusion from group studies. This is unfortunate given the promising
83 results from studies specifically targeting participants diagnosed with learning difficulties
84 associated with developmental disorders. For example, music-based interventions have
85 been shown to improve spelling in children with Dyslexia, and to increase social
86 responsiveness in children with Autism Spectrum Disorder (ASD; Finnigan & Starr, 2010;
87 Kern & Aldridge, 2006; Overy, 2003). Developmental disorders frequently show overlap
88 in terms of diagnosis and impairment, and this may be further complicated by symptoms
89 of developmental delay (e.g. sensory, memory, cognitive, motor and language difficulties).
90 For example, low motor competency is characteristic in both ASD and Attention Deficit
91 Hyperactivity Disorder (ADHD; Rasmussen & Gillerg, 2000; Geuze et al., 2001). Though
92 such difficulties may impact on musical learning, the development of motor skills using
93 musical intervention has been successful (Montello & Coons, 1998; Schoemaker et al.,
94 2003). For example, in Neurologic Music Therapy, Thaut and colleagues (1999; 2005;

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95 2015) have shown how rhythmic entrainment can be utilised optimize motor planning and
96 execution (alongside applications to cognitive, speech and language rehabilitation).

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

110

111

Method**112 Participants**

113 The subject of the case study (CB), together with a cohort of typically developing
114 seven to nine-year-old children (N = 38) participated in a musical learning study carried
115 out by the authors (Rose et al., 2017). Although CB did not have a statement of special
116 educational needs at the point of recruitment, pre-testing revealed that his scores on
117 standardized psychological tests varied as much as three standard deviations from the
118 group mean. Whilst these outlying scores meant that CB's data could not be included in
119 the analysis for the group study, his musical aptitude was good and his home environment

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120 was conducive to music learning. In the following section, we provide a characterization
121 of CB, including quantitative and qualitative data, to enable a full understanding of his
122 condition.

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Characterisation of CB

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

128 According to his mother, CB had been given a preliminary diagnosis of Asperger
129 syndrome at four years old, and during the period of the study he was further evaluated by
130 a clinical psychologist. This evaluation resulted in a formal diagnosis of Autism Spectrum
131 disorder (ASD), Attention Deficit Hyperactive Disorder (ADHD) and Visual and Auditory
132 Processing Disorder. The psychologist also reported that CB showed patterns of cognitive
133 impairment characteristic in Dyslexia and Dyspraxia¹. It is difficult to draw firm
134 conclusions about how CBs developmental difficulties might impact on his music learning
135 on the basis of this assessment. We therefore provide a précis of the characteristics of
136 these different diagnoses according to the Diagnostic and Statistical Manual (fifth edition,
137 DSM-V; APA, 2013).

138 ASD is a neurodevelopmental disorder diagnosed on the basis of social
139 communication difficulties and repetitive and/or restrictive patterns of behaviour, activities
140 or interests. Individuals with ADHD demonstrate persistent patterns of inattention and/or
141 hyperactivity-impulsivity that interfere with functioning in the home or school. Visual and
142 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.

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

149 At the beginning of the study, CB's teachers and parent expressed their belief that
150 music lessons could help him focus his attention, improve his communication skills and
151 provide an artistic outlet for his 'feelings'. It was clear that CB would receive significant
152 support from the adults in his life to enable this. In the initial data-gathering phase, parents
153 were asked questions about their attitude to music and their own level of musical
154 engagement. The rationale for this was that parental involvement is an important factor in
155 children's musical enrichment (Davidson, Howe, Moore, & Sloboda, 1996; Hargreaves,
156 1986). CB's mother reported that she played piano and guitar, and sang; writing, "Music
157 plays an important part of our daily lives". When asked about how important it was for
158 her child to have a musical education, she described it as 'essential'. Prior to learning the
159 tenor horn, CB had spent less than one hour each week engaging in music at school.
160 However, he spent up to three hours each week in self-motivated musical engagement at
161 home (dancing with mother and singing with siblings), and CB's mother reported that this
162 increased over the period of the study. At the start and end of the study, CB's mother
163 completed questionnaires about CB's activities and behaviours at home, his form tutor
164 about his school behaviours and his horn tutor provided a weekly account of his music
165 lessons. CB and the other children completed a battery of measures designed to offer a
166 comprehensive perspective of the concomitant development of his cognitive, behavioural
167 and social-emotional development in the first year of his musical learning. All measures

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168 were administered to the children individually except the PMMA which was administered
169 to the children in small groups. A description of these tests, and the reason for their
170 inclusion in this case study are detailed in the following section.

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172 **Measures**

173 As musical aptitude is likely to influence motivation, and potentially increase the
174 success of the music intervention, we used Gordon's Primary Measure of Musical
175 Aptitude (PMMA; Gordon, 1986) to measure CB's basic musical aptitude. In the test forty
176 pairs of musical phrases are presented in a same/different paradigm to test tonal and
177 rhythmic skills. For the tonal tests, these differ in pitch contour. For the rhythm test,
178 stimuli are presented on the same pitch but differ in note duration. The Beery (2004) test
179 of visual-motor integration was presented as a distractor task between tonal and rhythmic
180 tests². The Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999) was used
181 to measure CB's intelligence. The WASI includes Matrix Reasoning, Block Design,
182 Vocabulary and Similarities subtests, which combine to provide a Full Scale IQ score.
183 Performance IQ encompasses Matrix Reasoning and Block Design subtests and Verbal IQ
184 encompasses Vocabulary and Similarities subtests. The Children's Memory Scale (CMS;
185 Cohen, 1997) provides measures of short-term, long-term and working memory, and
186 executive function. In CB's assessment, Word List Learning and Word List Recall were
187 taken from Domain A, which measure auditory short-term memory and long term memory
188 consolidation respectively. Digit Span Forwards (DSF) and Digit Span Backwards (DSB)
189 and Sequences were taken from Domain C, which measures attention and concentration in
190 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.

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191 onto working memory (St. Clair-Thompson, 2010; St. Clair-Thompson & Allen, 2013).
192 Fine and gross motor abilities were assessed using the age appropriate tasks in the
193 Movement Assessment Battery for Children (Movement ABC-2; Henderson, Sugden &
194 Barnett, 2007). The Behavioural Assessment System for Children (BASC-2; Reynolds &
195 Kamphaus, 2004) assessed socio-emotional wellbeing from the perspective of the parent
196 and for teacher using 150-170 item questionnaires³ with items grouped into clinical and
197 adaptive scales. Ethical permission to carry out the study was granted by the Research
198 Ethics Committee at Goldsmiths, University of London.

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Results

201 Statistical Analyses

202 An aim of the study was to identify differences occurring during the period the of the
203 musical intervention between test scores at time 1 and time 2. This difference was divided
204 by the standard deviation for the group study mean to produce a measure of effect size
205 (Cohen's d). With the exception of the WASI (where IQ and T Scores are provided in line
206 with other studies), Table 1 provides data as percentiles (as well as Cohen's d) to enable
207 comparison between CB's and the group study results⁴ for the musically trained
208 participants from Rose et al., (2017). In the following section values of Cohen's d greater
209 than 1 were described as large.

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³ For BASC-2 parent report, the clinical scales of Anxiety, Atypicality and Withdrawal are missing due to 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.

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214 **Table 1. Case study results in the context of the group study¹**

Measure	Time 1		Time 2		Effect Size (Cohen's d)	
	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

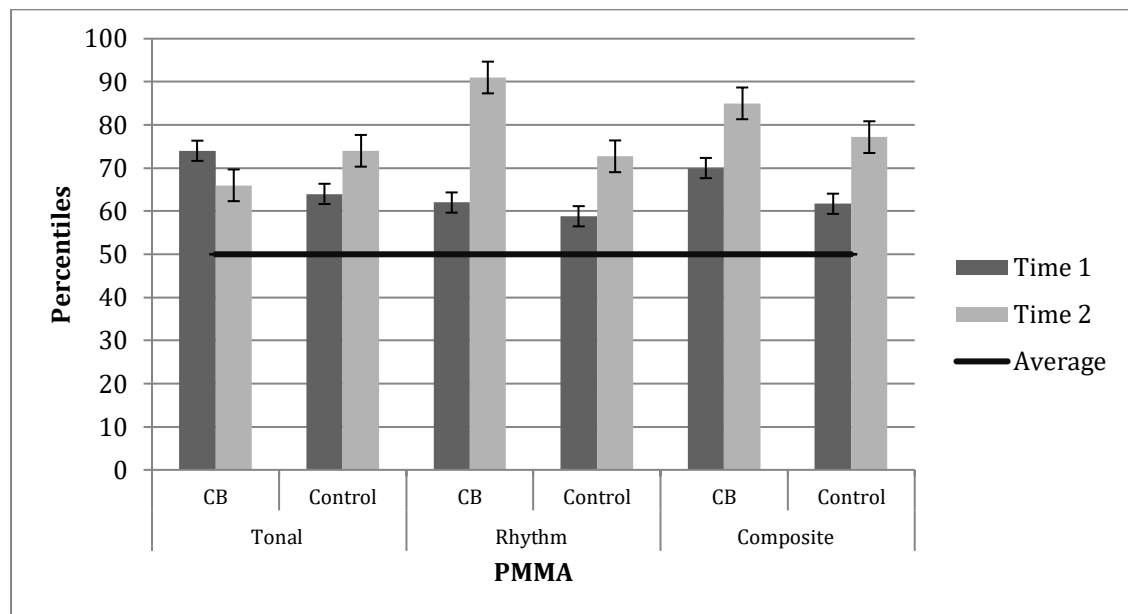
215 ¹Rose et al., (2017).

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

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

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

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

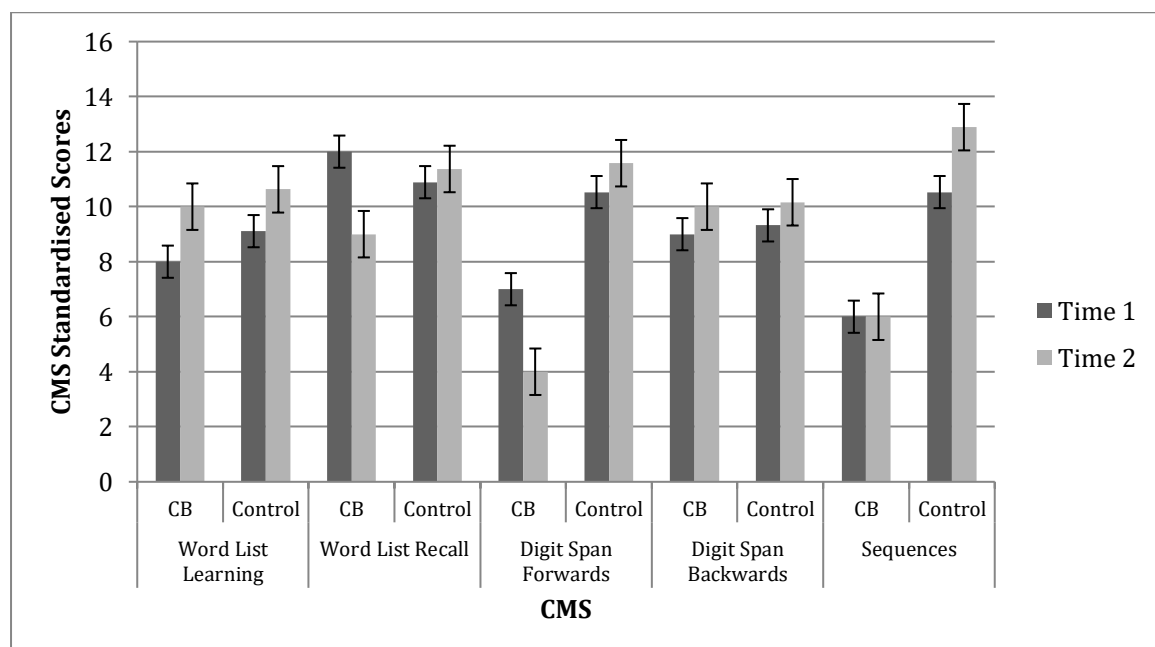
227 CB achieved average intelligence scores on the WASI, with a Full Scale IQ score of 103 at
 228 time 1 and 112 at time 2. Though this change was positive, it was less than 1 SD.
 229 However, as can be seen in Table 1, analysis of the sub-test scores revealed a large
 230 increase in performance on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

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

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



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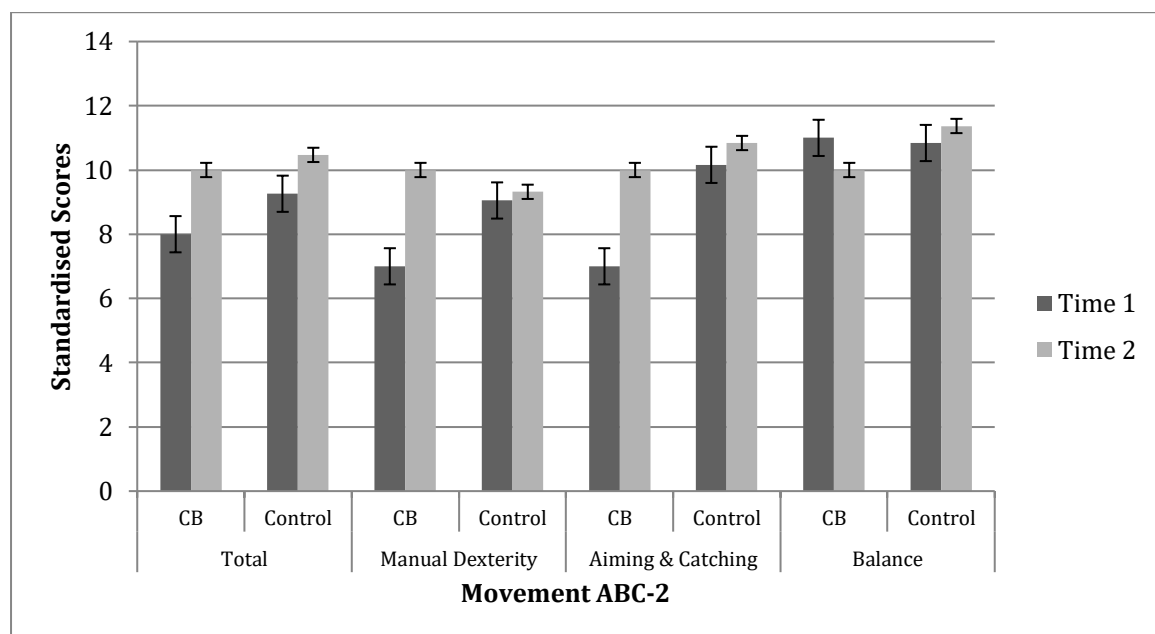
249 **Figure 2. Children's Memory Scale (CMS) comparison between CB and group over**250 **time**

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

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



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261 **Figure 3. Movement Assessment Battery for Children (Movement ABC-2)**262 **comparison between CB and group over time**

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

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267 As CB was diagnosed with ASD and ADHD, data from the scales that measure social
268 skills, attention problems and hyperactivity were of particular interest. In the pretest CB's
269 mother and teacher reported levels of Aggression, Conduct problems, Attention problems,
270 Hyperactivity and Depression that are flagged as a cause for concern in the BASC manual.
271 The pattern of test scores at time 2 showed considerable differences across teacher and
272 teacher reports, possibly reflecting variability in CB's functioning across home and school
273 environments. At time 2 testing CB's mother reported large increases in the clinical scales
274 of Attentional Problems and Hyperactivity. His form teacher reported a large decrease in
275 the adaptive scale of Social Skills (suggesting worsening socialization skills) and large
276 increases in the clinical scales of Aggression, Anxiety, Attention Problems, Conduct
277 Problems, Depression, Hyperactivity and Withdrawal. These changes suggest that CBs
278 learning and behavioural difficulties showed considerable deterioration over the year,
279 especially considering they were in marked contrast to the group scores (see Table 1),
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292 **Summary of Music Tutor Notes**293 **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

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295 The results from the standardized assessments revealed strong musical potential and
 296 average intelligence that co-occurred alongside difficulties in executive, motor, memory
 297 and social-emotional skills at time 1. CB's pattern of performance on the assessments at
 298 time 2 showed some areas of improvement (motor skills and fluid intelligence), decline
 299 (executive function and social-emotional behaviours) and stability (some aspects of
 300 memory) over the period of the study. In the following section the impact of CB's
 301 strengths and difficulties on his music learning will be explored. CB attended 26 half hour
 302 music lessons and the music tutor made extensive notes that are summarized in table 2⁵.
 303 In the lessons the music tutor focused on instrumental technique (embouchure formation,

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

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

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

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

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327 **Week 10** – “Got him to choose colours e.g. red for all C's, green
328 for all D's etc. He drew coloured circles around each note -
329 seemed to really enjoy it, and it helped with playing.”

330 **Week 11** – “He could play Hot Cross Buns today, looking at the
331 colour coded notes. It seems to work.”

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

335

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Discussion

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

340 At time 1, standardized tests provided a profile of an eight-year-old child (CB) that
341 suggested some apparent strengths (such as his musical aptitude and intelligence) as well
342 as potential areas of learning and behavioural difficulties (such as executive function and
343 inhibition). These results were mostly congruent with the complex diagnoses CB’s mother
344 reported receiving; although whilst such difficulties may be observed in children with
345 ADHD, Auditory and Visual Processing Difficulties, Dyslexia and Dyspraxia, they are
346 also observed in some children with ASD (Gargaro et al., 2011; Matson, Matson and
347 Beighley, 2011; Piek & Dyck, 2004). Deficits in attention, motor control and perception
348 (referred to as DAMP; Hellgren et al., 1994) have even been suggested as more clinically
349 relevant than the concept of ADHD (Kadesjö & Gillberg, 1998). However, the pattern of
350 social-emotional difficulties reported at time 1 are most strongly consistent with a

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351 diagnosis of ASD and appeared to confirm CB's preliminary diagnosis of Asperger
352 Syndrome at 4 years old. Though these difficulties might have impacted upon his musical
353 learning abilities, the aim of the mother and school in providing musical instrument
354 lessons for CB was to improve his focus and attention skills whilst also finding an artistic
355 outlet for his emotions. This idea is suggestive of the notion of transfer effects from
356 musical learning. Testing at time 2 showed a diverging pattern of change which helps us
357 understand how CB's condition impacted positively and negatively upon his musical
358 learning, and potentially vice versa. To begin with we discuss the concept of near transfer
359 effects in terms of musical aptitude and motor skills in relation to CB's diagnosis.

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

374 In relation to his musical abilities, CB's score on the Rhythm component of the
375 PMMA increased from the 62nd to the 91st percentile over time. This suggests that CB

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

386 Musical training has also been associated with positive changes in cognitive
387 measures, which have been suggested as far transfer effects of musical learning, such as
388 reading and spelling (Butzlaff, 2000; Overy, 2003) and non-verbal reasoning (Vaughn,
389 2000; Hyde et al., 2009). CB had average IQ at time 1, a result which is in line with
390 research by Charman and colleagues (2010) reporting that 55% of children with ASD
391 obtain IQ scores that are in the normal range. CB's overall IQ increased from 103 to 112
392 (within confidence intervals, as was the group finding). However, CB also showed a large
393 increase on the Matrix Reasoning subtest of the WASI (also in line with the group study,
394 Rose et al., 2017). The Matrix Reasoning sub-test assesses pattern detection, reasoning and
395 problem-solving in fluid intelligence (Wechsler, 2003).

396 It seems likely that a combination of CB's dyslexia, visual processing and
397 executive functioning difficulties impeded his ability to read the notes on the stave.
398 However, we know from the horn tutor's notes that CB was keen to engage in finding a
399 solution to this difficulty, and together they identified a colour coding scheme to help CB
400 understand the musical notation. As Matrix Reasoning is essentially a pattern matching

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401 task, the positive result of this sub-test of the WASI suggests that CB may have applied his
402 problem-solving skills to help him overcome this difficulty. Together these results suggest
403 some benefits of musical learning in terms of transfer effects, but it is important to
404 acknowledge that these changes occurred within a supportive environment. The interaction
405 between horn tutor, who was sensitive to the students' individual needs, combined with the
406 opportunity provided by the supportive school, and a musically engaging home-life,
407 afforded the syzygistic alignment of environments that supports musical development in
408 children (McPherson, Davidson & Faulkner, 2012).

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

421 CB was aware of his diagnosis and conscious of his learning difficulties and
422 behavioural problems. These results suggest that some concurrent emotional difficulties
423 may have been impacted on CB's learning and behaviours. Further observations support
424 this suggestion. For example, when CB was repeating musical phases out loud during the
425 administration of the PMMA, he was also able to secure popularity by gaining laughs from

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426 his peers. Though this behaviour in itself is not necessarily symptomatic of his
427 developmental difficulties, it suggests that CB had acquired some useful strategies to
428 create some emotional insulation that protected him in an environment which he found
429 psychologically challenging. The horn tutor noted these behaviours too (i.e. using
430 charisma to deflect focus away from his own uncertainty of the task). Elliott (1993)
431 suggests that musical learning provides a goal-directed pleasurable reward system, and
432 through this, musicians acquire a sense of the autotelic value of practice. For CB, it was
433 critical that the horn tutor was motivated to help him overcome his difficulties. He
434 established a good one-to-one relationship and adapted his teaching techniques to
435 accommodate CB's learning problems. Additionally, the school also put systematic
436 behavioural and organizational boundaries in place. Weekly lessons could not be re-
437 arranged, practice was expected, and specific goals continued to provide motivation for
438 CB who wanted to perform with the school band in the end of year music festival.

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

449 Finally, the combination of measures in this case study also provides other
450 potential insights into musical learning for children with special educational needs, that

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

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476 2003) we tentatively suggest that the reported strategy (of repeating the sounds) would
477 help CB hold the musical phrases in his phonological loop (Baddeley, 1992; Klingberg et
478 al., 2002; Lee et al., 2007). This could explain the disparity between short-term and
479 working memory evident in the forward and backward digit span test of the CMS results
480 (see figure 2). However, we acknowledge that CB's performance on the Sequences test
481 showed a stable deficit in executive function and it is possible that difficulties in attending
482 associated with ASD, and the related difficulties associated with his complex diagnosis
483 effected these scores (O'Hearn, Asato, Ordaz & Luna, 2008).

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Limitations

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486 Though this case study presents novel data regarding individual differences in
487 comparison to group statistics, it is important to note that developmental trajectories may
488 differ between the children. In particular, poor performance on measures of motor ability
489 may be predicted developmental delay (Allerton, Welch & Emerson, 2011; Dewey et al.,
490 2002; Hinckson & Curtis, 2013). With the co-morbid diagnosis including motor deficits
491 and ADHD at his particular age, there is evidence to suggest that these conditions may be
492 particularly significant for males (Pitcher, Piek & Hay, 2003). Other issues pertaining to
493 generalizability concerning measurement error due maturation and regression to the mean
494 should also be noted (Feinstein et al., 2015). However, by comparing this individual with
495 the group study by Rose and colleagues (2017), it is possible to demonstrate the magnitude
496 of observed changes within an appropriate context.

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Conclusion

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About the Authors

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Addition to Author Note

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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.

Dawn Rose is a postdoctoral research fellow investigating the effect of music on motor behaviours in people with Parkinson's. Dr. Alice Jones Bartoli is a Senior Lecturer and Director of Unit of School and Family Studies. Her research interests include the development of antisocial behaviours and socio-emotional processing skills in children. Professor Pamela Heaton specializes in development disorders. Her research interests include the relationship between speech and music perception in autism spectrum disorder and William's syndrome.

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

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 528 *Musicianship in Children and Adults.* (Doctoral dissertation). Goldsmiths, University of
 529 London. Retrieved from http://research.gold.ac.uk/19105/1/PSY_thesis_RoseD_2016.pdf.

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534

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