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Corresponding Author: Dawn Rose, PhD. D.rose3@herts.ac.uk

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Title: A study of cognitive and behavioural transfer effects associated with children learning musical instruments for the first year over one academic year.

Abstract

Interest in studies investigating the indirect effect of music education, evaluated theoretically as 'transfer effects' (Barnett & Ceci, 2002) has been re-energised by the recent changes in policy that require musical provision to be justified (Branscombe, 2012). Here we take a holistic approach to musical learning, nesting neuro-psychological measures of near and far transfer within one battery of tests. The mixed design considered the multi-modal characteristics of musicality along a continuum assessing changes over time for behavioural visuo and psycho-motor skills and factors of both intelligence and memory in children in a pilot study. Participants (N=38) aged between 7-9 years were tested over a period of one UK academic year. Groups were assigned based on the amount of musical training they received. Results suggest an advantage for

those participants taking music lessons over and above statutory provisions, particularly for hand/eye coordination and nonverbal reasoning.

Background

Musical learning has been described as a ‘superskill’ (Stewart, 2008) with the multiplicity of skills observed as “involving complex cognitive and bimanual motor skill acquisition as well as sensory stimulation” (p.205 Schlaug et al, 2009) and further incorporating aural, cognitive, technical, communicative and reflexive practice (Hallam, 1998).

The range of skills developed when learning a musical instrument are typically referred to as ‘transfer skills’ when the benefits are not thought to be localised (domain-specific) to the type of musical training (Amunts et al. 1997). The notion of ‘near transfer’ identifies the skill learned with a closely related ability, such as learning to play the piano enhancing fine motor skills (Costa-Giomi, 2005). ‘Far transfer’ effects (for example when musical learning is associated with IQ, mathematical or literacy measures) are considered problematic, not only because of contradictory evidence, but also in part caused by the lack of unified theory and methodological inconsistency (Jaschke et al, 2013).

We focus here specifically on visuo/motor skills as near transfer, and factors of IQ and memory as far transfer in that they are at least testable measures within the cognitive and behavioural domains.

Visuo/Motor Skills

The complexities involved in planning and executing complex motor sequences, simultaneously coordinating and controlling independent movements with multiple body parts, integrating auditory, visual, tactile and proprioceptive information in a constant dynamic monitoring mode supports the notion of 'metaplasticity' (Schlaug et al, 2010). Research evidence suggests that the mirror neuron system, situated in the posterior inferior frontal gyrus and the arcuate fasciculus (i.e. the auditory-motor fibre bundle) are implicated in the musical training 'advantage' (Lahav et al, 2007). Wan & Schlaug (2010) propose a specialised '*hearing-doing, seeing-doing'* network which they identity as the frontotemperoparietal region suggesting that, as the limbic system is actively engaged in processing, thisaccounts for associated pleasurable rewards, resulting in motivation to play. As an example of near transfer, musically trained children have been found to have superior fine motor skills (e.g. motor tapping associated with rhythmic discrimination abilities) in several studies (see e.g. Amunts et al, 1997; Costa-Giomi, 2005, Forgeard et al, 2008). With regard to visuo-motoric skills, musical notation reading has been correlated with differences in grey matter volume and activation response associated with the superior and inferior temporal cortex in visuo-spatial processing tests (Gaser & Schalug, 2003) and activation in the parietal cortex was present even when musical notation was simply observed (Stewart et al 2003). Training before the age of seven also appears to impact on visuo-motor abilities (Watanabe et al 2007). Furthermore, a meta-analysis carried out by Butzlaff (2000) supported a significant association between musical training and reading skills. However, as Forgeard et al (2008) point out; it is not possible to establish evidence of far transfer without first accounting for near transfer learning in the parent domain. Consequently, the evidence presented here attempts to reify this confound utilising the Beery Visuo-Motor Index (Beery VMI – Beery et al, 1997) and Movement Assessment Battery for Children (MABC – Henderson et al, 2007) measures.

Intelligence

The possibilities of neuro-psychology invite us to investigate and invest in the neural correlates of learning, but with caution for as Boring declared in 1923, 'Intelligence is what intelligence tests measures'. Therefore, when considering findings referred to transfer effects, it is important to reflect upon Ferguson's Law – i.e. that culture will prescribe what is learned by whom and at what age (Kauper, 1954). However, necessity often demands a pragmatic approach and in order to consider the 'deeper insight concerning the nature of musical learning' (Jaschke e al, 2013) we must first unpack the evidence available under the umbrella term of intelligence.

Initially, Schellenbergs' 2004 study was taken as evidence that extra musical learning (34 week period) could predict a significant increase in IQ scores for 6 – 11 year old children, although the largest effect was found for singing rather than instrumental (keyboard) training groups. Schellenberg later argued (2006) that the advantage is a result of increased focussed attention, memorisation and progressive mastery of a skill because musical lessons actually function as additional schooling, for which there is well-established evidence [that general schooling] enhances IQ scores(Ceci & Williams, 1997).

Rather than looking at attainment in other equally key areas (such as mathematics and literacy), we considered the component factors measured within tests of IQ. We administered the Weschler Abbreviated Scale of Intelligence (WASI – Weschler, 1999) to obtain data on vocabulary, matrix reasoning (nonverbal skills), block design (spatial ability) and similarities (semantic processing). The use of this test enabled us to measure potential changes in specific cognitive mechanism, after our musical intervention (see e.g. Hetland, 2000, Hetland & Winner, 2004; Forgeard et al, 2008)

Memory

Whilst there is general agreement that long term musical memory seems to categorise and contextualise events according to a musical hierarchy of rules known as a *schema* (Bregman, 1990; Lerdahl & Jackendoff, 1983), evidence that music training is related to improvements in short term memory is contradictory (see e.g. Levitin & Cook, 1996; Williamson et al, 2010). Working memory is an umbrella term for several separate systems thought to include echoic memory trace, a visuo-spatial sketchpad, a phonological loop, a central executive and an 'episodic buffer' (Baddeley & Hitch, 1974, Baddeley 2003). These study of these components of memory, which are separately testable as discriminatory skills, may further help us understand, for example, about how reading musical notation and language processing are implicated in executive function, attention and inhibition. As there appears to be some overlap between working memory and language skills (Schulz et al, 2011), it is possible that the process of 'binding' (Baddeley, Allen & Hitch, 2010) may explain why children learning musical instruments have showed superior verbal memory skills (Butzlaff, 2000; Ho et al, 2003). We included sections of The Children's Memory Scale (Cohen, 1997) in our test battery in order to isolate aspects of memory that were subject to change during the first year of musical training.

Methodology and Measurement

This study took place over one academic year with Time 1 occurring September 2013 and Time 2 observations in June 2014 (N=38). The mean age at T1 was 93 months (SD 5.54) with 21 female and 17 males, 22 of whom attended state schools and 16 independent schools. The mean IQ was 106 (SD 13.77 - Range 74 – 133). 20 participants were classed as having more than one hour of optional extra musical lessons (a mixture of instruments) per week (More Music Group MMG), whilst 18 received less than this as part of their schools statutory curricular provision (Less Music Group LMG).

Systematic analysis began with paired t tests and simple RM ANOVA with the groups divided as less and more music. Missing data was not replaced with averages. Further analysis utilised split plot profile techniques for RM ANOVA whereby either the differences between Time 1 and Time of the variable where compared within each composite test (See Tables and Figures below) or the number of hours per week could be analysed according to different comparative activities (Musical, Physical and Leisure). The Gordon's Primary Measure of Musical Audiation (PMMA – Gordon, 1986) was also recorded at both time points in order to assess the participants' musical aptitude.

Ethics

Ethical approval for this project was granted by the Goldsmiths Psychology Research Ethics Committee. Participants, their parents and teachers were informed both of the nature of the research, the aims and objectives and anonymous use of results adhering to the Data Protection Act. Every effort was made to facilitate fully informed consent and the protection of individual rights regarding the anonymous use of data and the right to withdraw from the study at any time. Clear and transparent English was used. Active parental consent was required for participation. The researcher was fully trained in the test battery and has appropriate DBS clearance and training in safe-guarding children. Standards for Education and Psychological Testing (APA, 1985) were adhered to.

Results

Student T tests showed both groups increased their scores over time for the GPMMA. This effect was only not significant for the MMG who showed an advantage (though no statistical difference) over the LMG (see Table 1 and Figure 1). There were significant main effects of time for the Composite ***F*(1,35)=27.961, *p*=<.001** and for the Tonal ***F*(1,34)=8.098, *p*=.007** and Rhythm ***F*(1,35)=16.172, *p*=<.001** components, but no interactions.

For the WASI, significant T tests revealed an advantage for the more music group over time for the Full 4 Factor score as for the vocabulary and matrix reasoning components (See Table 2 and Figures 2 and 3). RM ANOVA confirmed the full four factor result ***F*(1,35)=4.845, *p*=.034** although this would become ns if αp.05/7=.007). The full four can be further analysed as performance/fluid intelligence (PIQ = ns) and verbal/crystallised intelligence (VIQ = *F*(1,35)=3.902, *p*=.056). Further RM ANOVA analysis revealed the Vocabulary factor did not meet the assumptions required for parametric analysis, so Wilcoxon Signed Rank test were employed showing the MMG increasing their scores significantly ***Z*= -2.175, *p*=.030**, whereas the LMG did not. Matrix Reasoning ***F*(1,35)=4.796, *p*=.035** but this would become ns when corrected for multiple comparisons based on αp. A split plot profile (See Figure 4) on all four factors of WASI, sphericity assumed showed a significant overall effect of these measures over time based on the differences between time 1 and time 2, but no significant interaction between groups ***F*(3,35)=3.718, *p*=.014.**

Table 3 and Figure 5 illustrate the results for the Children's Memory Scale. Initial analysis suggested a difference between the groups regarding the numbers (digits) forward (advantage LMG) and numbers backwards (advantage MMG). Of these, only the numbers total composite score remained significant ***F*(1,36)=8.791, *p*=.005** through the RM ANOVA, although there was no significant interaction. Both groups however improved significantly for the sequences subtest

LMG: ***Z* = -3.656, *p*=<.001**; MMG**: *Z* = -3.210, *p*=.001** even after corrected for multiple comparisons. When considering all six factors of memory tested on difference, a split plot profile again suggested a significant effect over time ***F*(5,35)=5.147, *p*=.001** – Sphericity not assumed, Greenhouse-Geisser corrected result reported (see Figure 6).

For the Movement ABC (see Table 4 and Figure 7), the Total composite was significant ***F*(1,36)=5.610, *p*=.023**, but this disappeared when corrected as αp=.05/4=.0125. However, the Aiming & Catching composite was significant over time for the MMG ***F*(1,35)=8.754, *p*=.006**, even when corrected. Of the subtests, both the ball throwing and catching ***F*(1,35)=8.112, *p*=.007** and the bean bag target throwing appeared to be significantly affected over time. However, again this effect disappeared when correcting for multiple comparison (αp=.05/13=.003). The overall model was not significant although a split plot profile of the differences is included (See Figure 8). Using the split plot profile technique in a different way, when accounting for the amount of hours per week participants spent doing musical activity, we could see there was a significant effect of intensity Between Subjects ***F*(4,6)=16.194, *p*=.002** to a greater magnitude than that found for physical activity Between Subjects ***F*(4,6)=6.16, *p*=.026** and no effect found for leisure time.

Finally, the Beery tests did not indicate any significant change over time for either group on any of the components (See Table 5 and Figure 8).

Table 1. Gordon's Primary Measure of Musical Aptitude Results

Gordon's Primary Measure of Musical Audiation					
Composite T Score	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	60.79	5.432	66.59	3.355	t(18)-4.561, p=<.001
Extra Music (More) N=18	64.5	6.776	68.22	4.747	t(17)-2.925, p=.009

Tonal	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	32.72	2.347	34.39	2.2	t(17)-2.976, p=.008
Extra Music (More) N=18	34.61	3.6	35.89	3.046	NS
Rhythm	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	28.58	3.834	32.11	2.514	t(18)-3.699, p=.002
Extra Music (More) N=18	29.89	4.431	32.33	3.01	t(17)-2.132, p=.048*NS if alpha p.05/3 = .016

Figure 1 – Gordon's Primary Measure of Musical Aptitude Chart

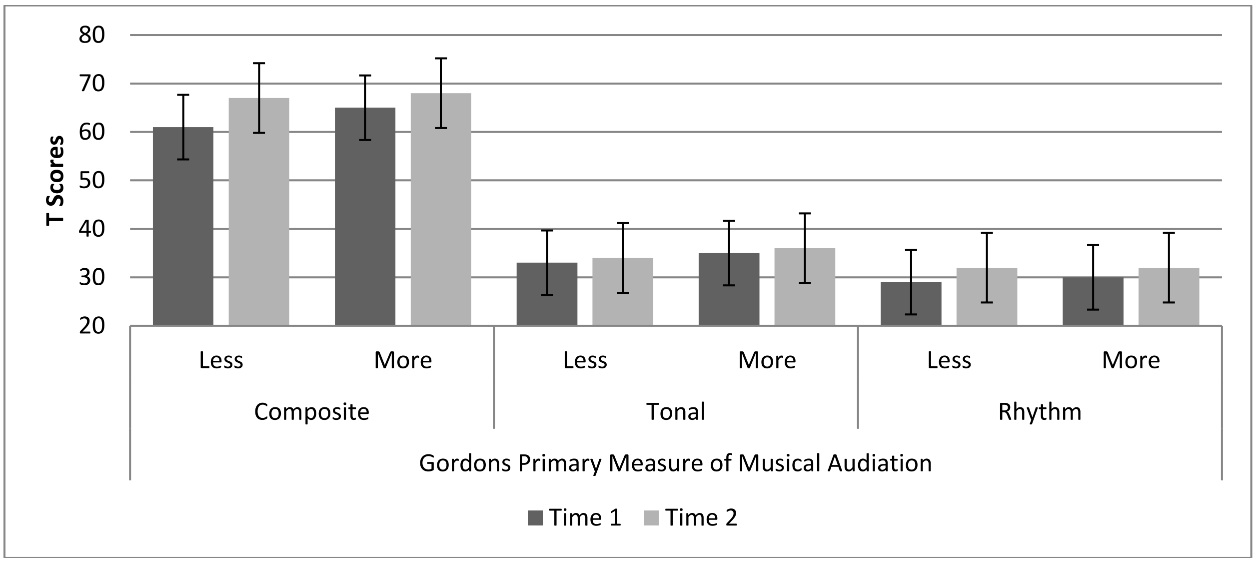


Table 2. Weschler Abbreviated Scale of Intelligence Results

WASI IQ					
Full 4 T Score	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	208.17	25.46	210.28	22.43	ns
Extra Music (More) N=19	218.47	33.87	239.84	29.58	t(18)=-2.341, p=.031
VIQ	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	108.28	15.3	110.22	15.65	ns
Extra Music (More) N=19	113.89	20.71	121.58	17.89	ns (p=.060)
PIQ	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	99.89	18.01	100.61	12.78	ns
Extra Music (More) N=19	104.58	19.36	108.74	15.86	ns
Vocabulary	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	50.33	6.84	53.94	10.37	ns
Extra Music (More) N=19	52.95	15.46	60.42	12.05	t(18)=-2.311, p=.033

Similarities	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	56.89	11.11	56	10.33	ns
Extra Music (More) N=18	61.95	15.46	61.95	9.82	ns
Matrix Reasoning	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	50.89	11.08	52.78	7.67	ns
Extra Music (More) N=18	51.79	10.01	56.42	8.29	t(18)=-2.764, p=.013
Block Design	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	50.22	10.29	47.39	8.2	ns
Extra Music (More) N=18	51.47	11.83	52.74	8.68	ns

Figure 2. Weschler Abbreviated Scale of Intelligence Overall Chart

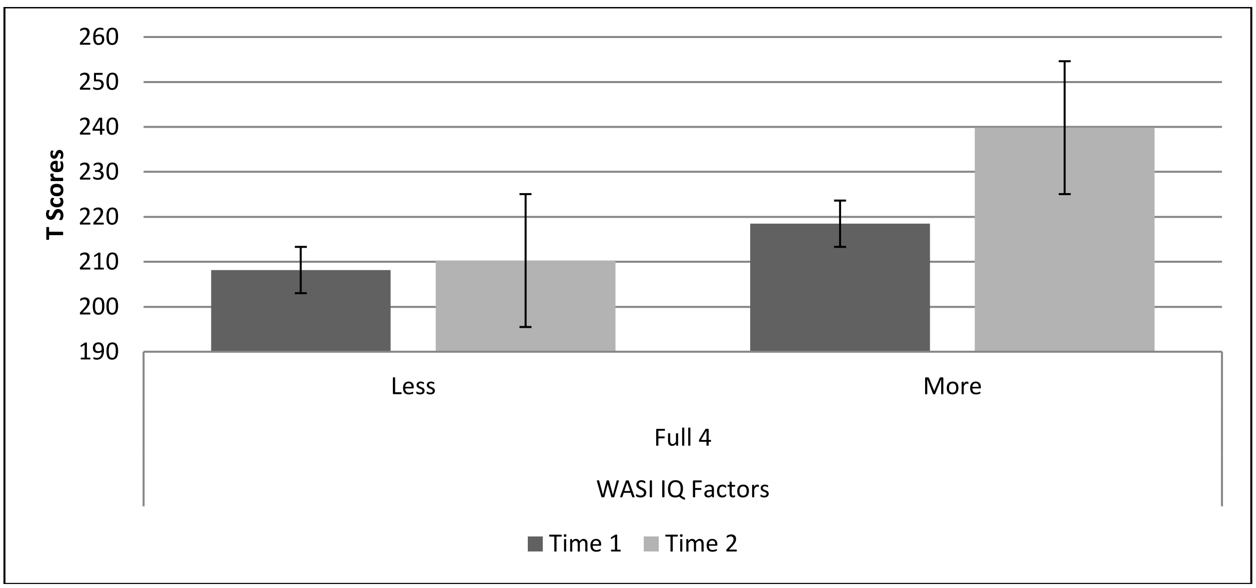


Figure 3. Weschler Abbreviated Scale of Intelligence Factor Chart

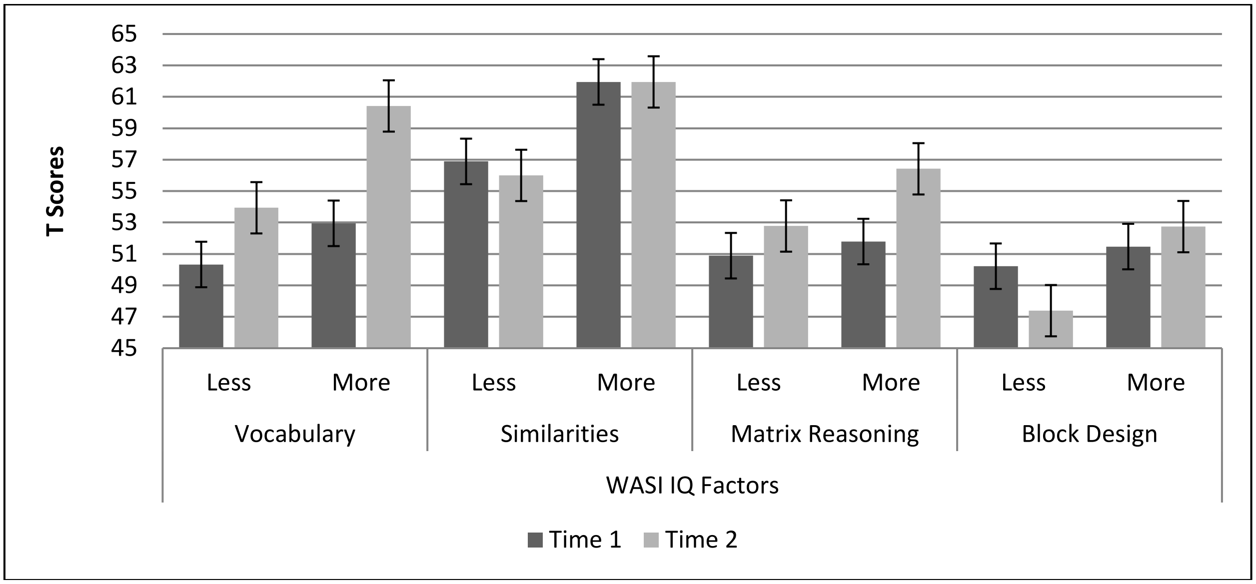


Figure 4. Split Plot Profile Illustrating Four Factors of WASI over time

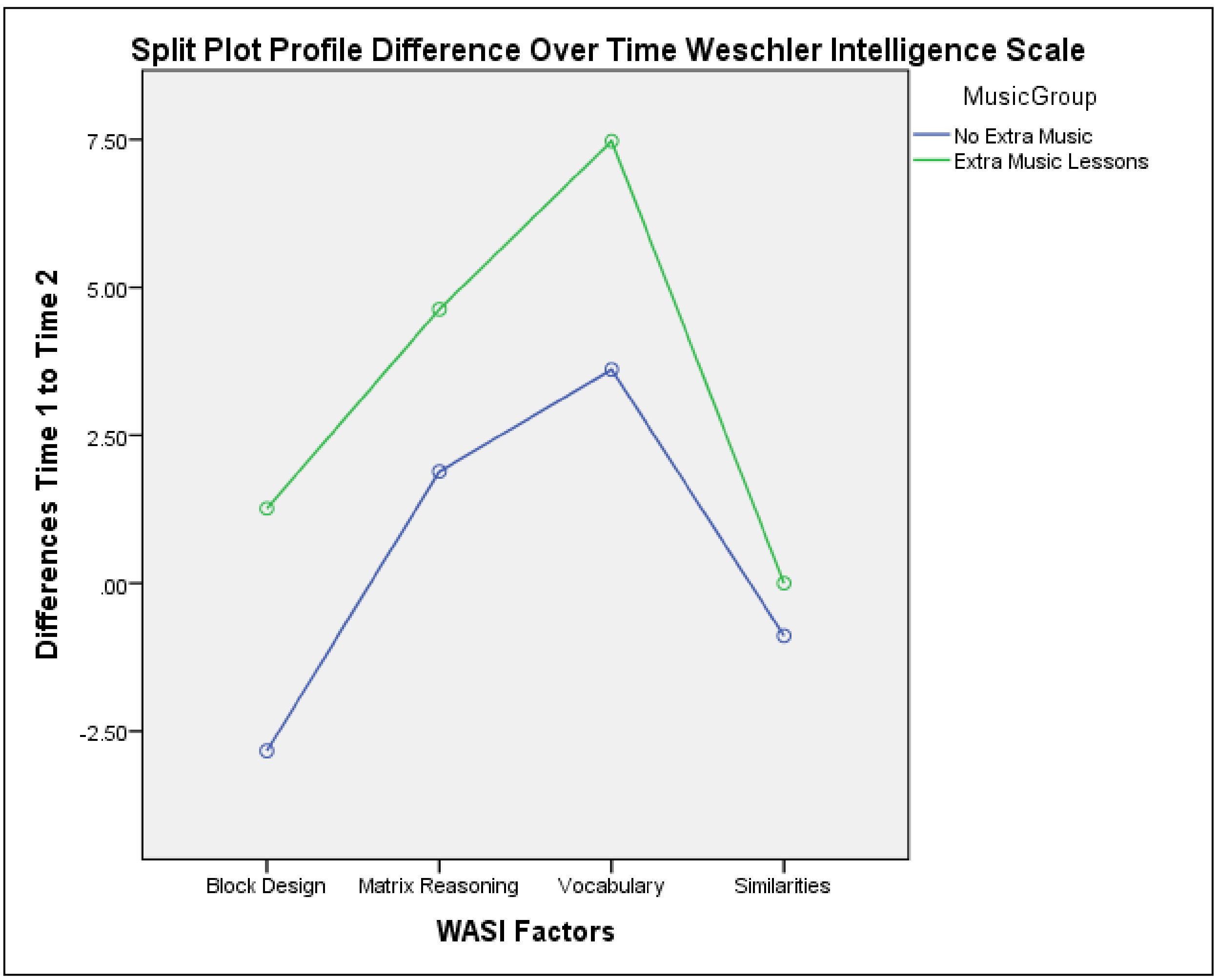


Table 3. Children's Memory Scale Results

Children's Memory Scale					
Word List Learning	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	10.37	2.89	11	3.21	ns
Extra Music (More) N=19	9.11	3.38	10.74	3.19	ns
Word List Recall	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	12.37	3.04	11.32	2.67	ns
Extra Music (More) N=19	11	2.69	11.53	2.59	ns
Numbers Forward	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	11.16	2.75	12.68	2.38	**t(18)=-3.222, p=.005 Sig even after correcting alpha p=.008**
Extra Music (More) N=19	10.63	3.25	11.32	3.46	ns
Numbers Backwards	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	10.16	2.71	10.74	2.66	ns
Extra Music (More) N=19	8.89	2.18	10.58	3.08	**t(18)=-2.044 p=.056 ns after correcting**
Numbers Total	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	11.16	2.65	12.42	2.5	**t(18)=-2.759, p=.013 ns after correcting**
Extra Music (More) N=18	10.16	2.76	11.21	3.36	ns
Sequences	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9.89	2.14	12.72	1.81	**t(17)=-8.438, p=<.001**
Extra Music (More) N=18	10.47	3.56	12.79	3.81	**t(18)=-4.462, p=<.001**

Figure 5. Children's Memory Scale Factors Chart

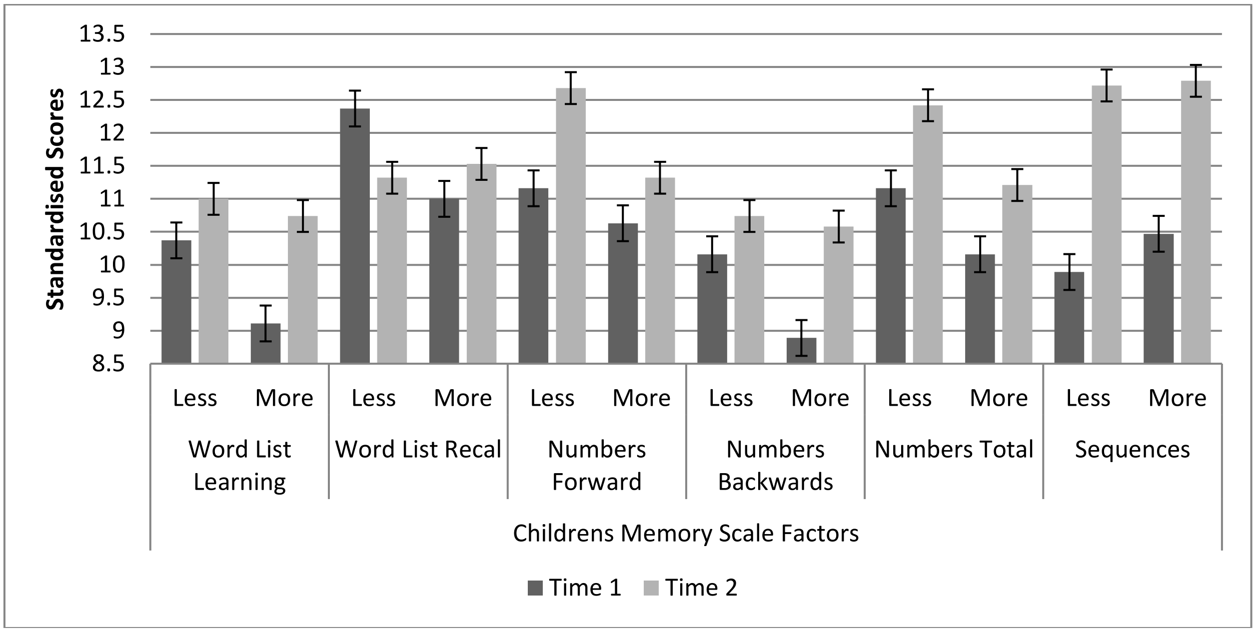


Figure 6. Split Plot Profile of Children's Memory Scale Factors

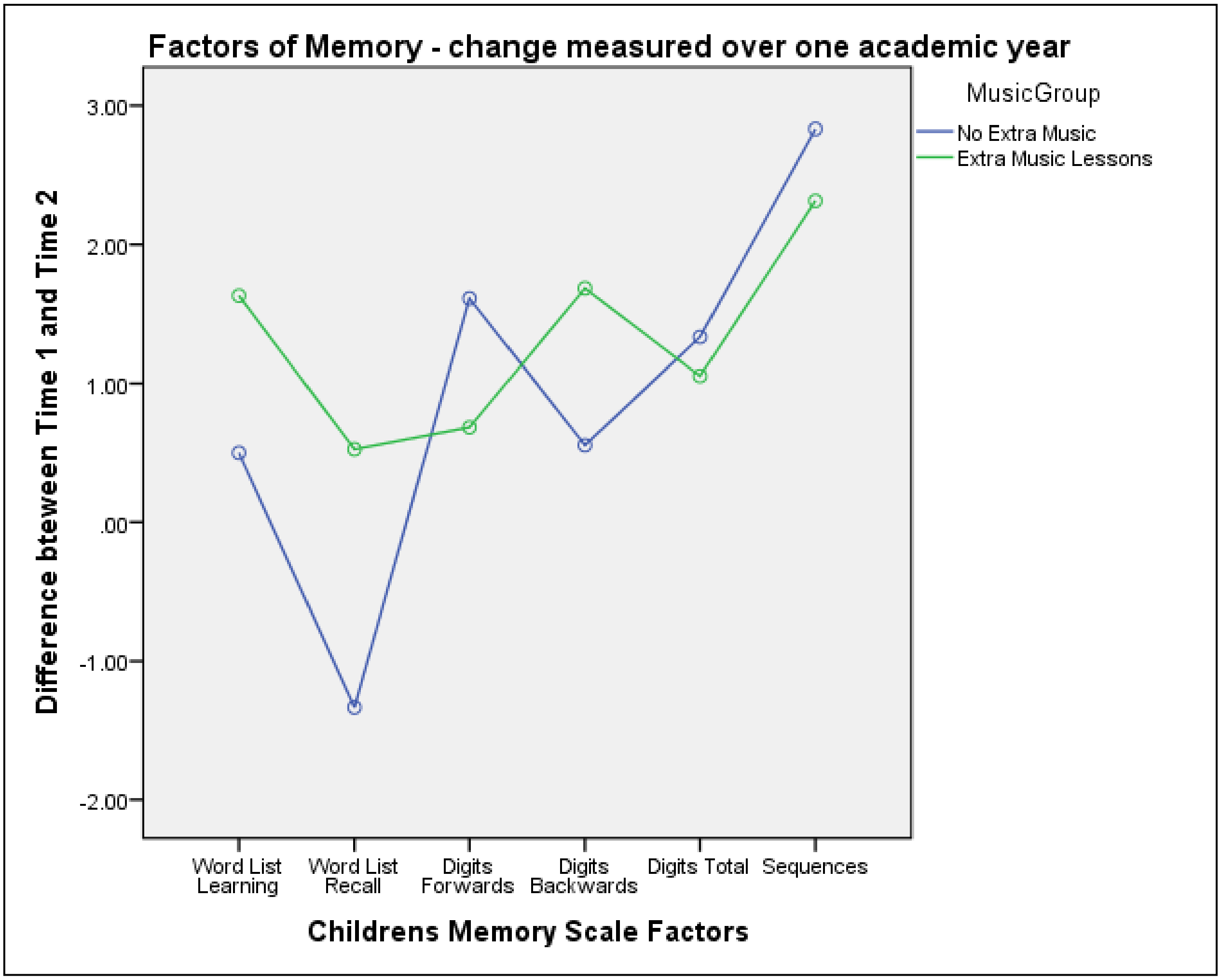
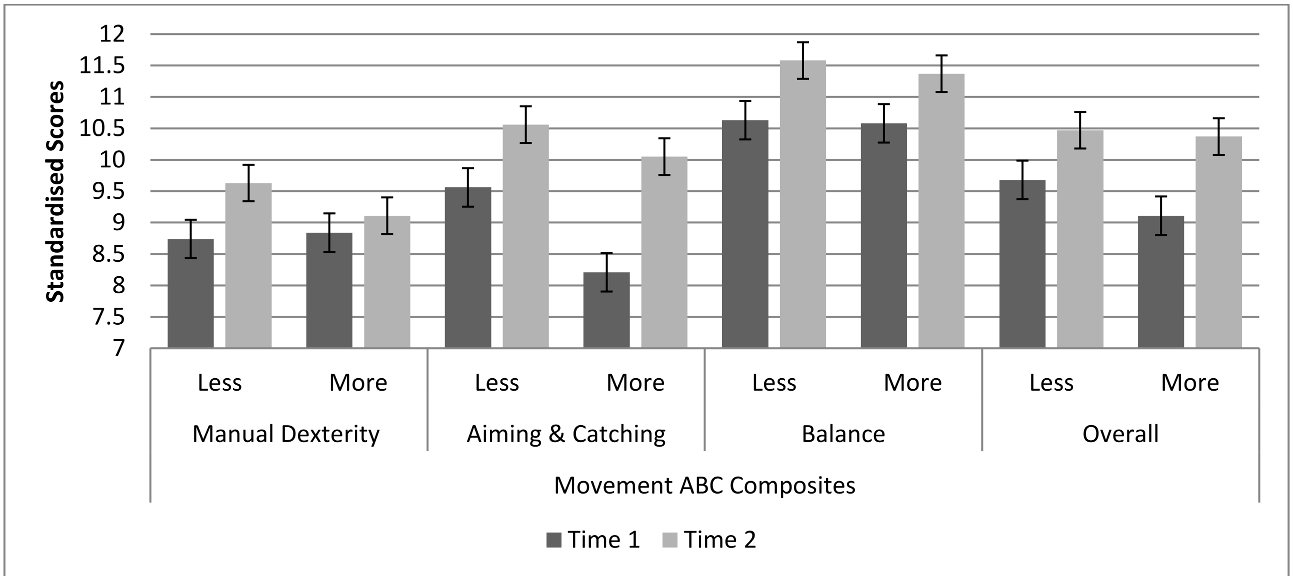


Table 4. Movement ABC Results

Movement ABC					
Manual Dexterity Composite	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	8.74	3.36	9.63	3.56	ns
Extra Music (More) N=19	8.84	2.57	9.11	3.59	ns
Aiming & Catching Composite	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	9.56	2.9	10.56	2.68	ns
Extra Music (More) N=19	8.21	1.81	10.05	2.63	**t(18)=-3.053, p=.007 (sig even when corrected as alpha p=.05/4=.0125)**
Balance Composite	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	10.63	2.19	11.58	2.8	ns
Extra Music (More) N=19	10.58	1.98	11.37	2.67	ns
MABC Total	Mean	SD T1	Mean	SD T2	Paired T Test Statistic

	T1		T2		
No Extra Music (Less) N=18	9.68	2.67	10.47	2.5	ns
Extra Music (More) N=19	9.11	1.91	10.37	2.85	ns
Preferred Hand Placing Pegs Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9.42	2.91	8.21	3.58	ns
Extra Music (More) N=18	10.68	2.73	10.11	2.28	ns
Non-Preferred Hand Placing Pegs Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9.52	2.67	9.32	2.69	**t(18)=3.211, p=.005 TIMED but ns when corrected**
Extra Music (More) N=18	11	2.05	9.58	2.27	ns
Both Hands Threading Lace Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9.37	3.39	11.47	3.06	**t(18)=3.327, p=.004 TIMED (ns when corrected as alpha p=.05/13=.003) ALSO t(18)=-2.219, p=.040 Stand' but ns when corrected**
Extra Music (More) N=19	11	3.02	11.74	2.56	**t(18)=2.486, p=.023 TIMED but ns when corrected**
Drawing a Trail Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	6.74	4.08	7.47	4.17	ns
Extra Music (More) N=19	5.11	3.23	5.84	3.37	ns
Catching a Ball Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	10.11	2.81	11.5	2.75	ns
Extra Music (More) N=19	8.84	1.71	10.26	3.25	ns
Throwing a Bean Bag to Target Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9	3.32	8.53	3.19	**ns**
Extra Music (More) N=18	7.11	2.16	9.42	3.13	**t(18)=-2.775, p=.012 Stand' but ns when corrected**
Preferred Leg Balance Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	9.47	3.19	10.79	4.17	**t(18)=-3.605, p=.002 TIMED - sig even when corrected**
Extra Music (More) N=18	11.16	2.91	11.63	2.89	**ns**
Non-Preferred Leg Balance Standardised	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=19	7.42	2.69	8.58	4.27	**t(18)=-2.536, p=.021 TIMED but ns when corrected**
Extra Music (More) N=18	7.53	3.4	8.84	3.45	**t(18)=-2.448, p=.025 TIMED but ns when corrected**

Figure 7. Movement ABC Factors Chart



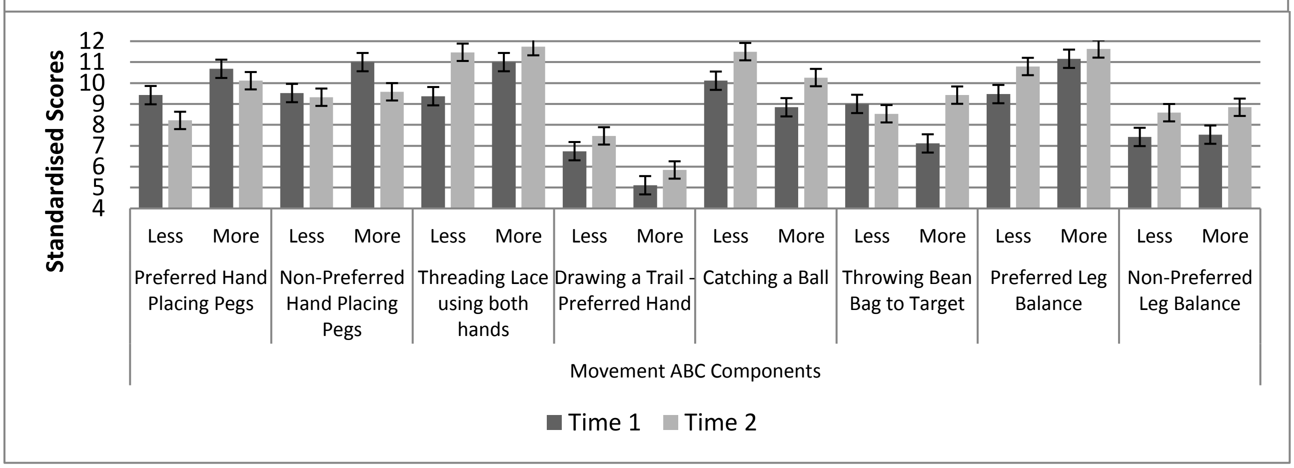


Figure 8. Split Plot Profile of Differences for Movement ABC Components

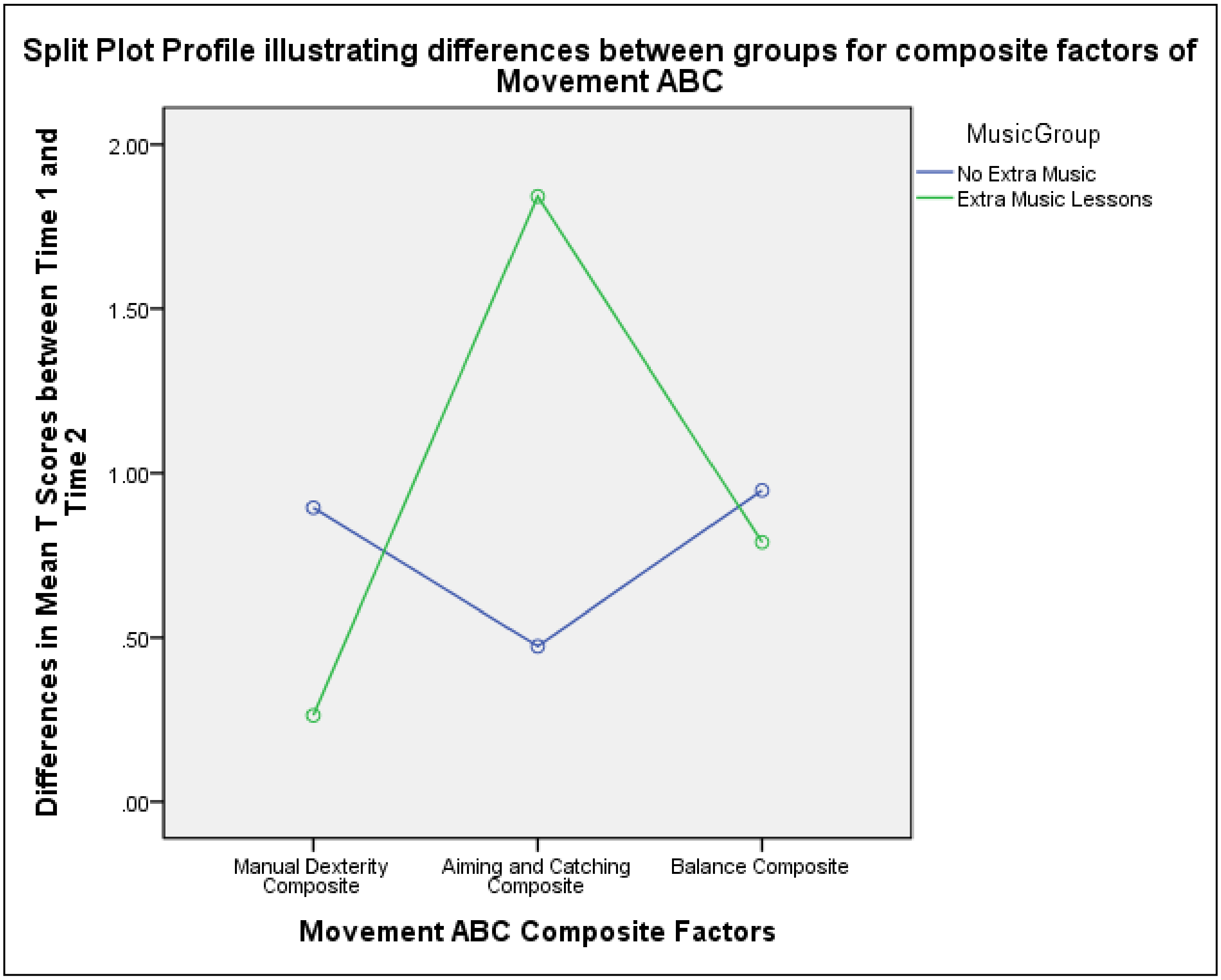
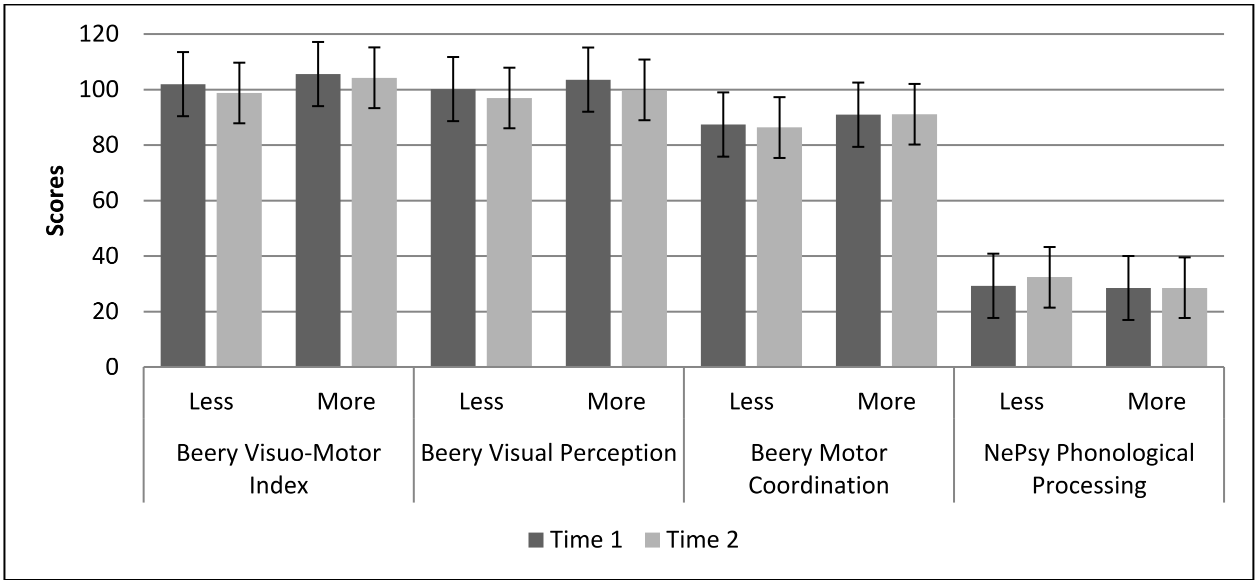


Table 5. Beery Results

Beery					
Visuo-Motor Index	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	101.95	12.92	98.74	7.44	ns
Extra Music (More) N=19	105.59	13.73	104.24	14.67	ns
Visual Perception	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	100.18	16.14	96.94	17.94	ns
Extra Music (More) N=19	103.57	17.59	99.86	12.02	ns
Motor Coordination	Mean T1	SD T1	Mean T2	SD T2	Paired T Test Statistic
No Extra Music (Less) N=18	87.39	6.59	86.33	12.52	ns
Extra Music (More) N=19	90.94	13.85	91.11	16.31	ns

Figure 9. Beery Results Chart



Discussion

Whilst it may not be surprising that those children with a higher musical aptitude chose to take extra music lessons, it is perhaps of interest that this advantage was negated as the children receiving statutory music lessons group caught up over the year. Gordon suggests that any natural aptitude stabilises and becomes less trainable from the age of 9 years (1998). Therefore this evidence could be taken to support his idea of a developmental plateau. However, further analysis needs to investigate multi-factorial dependence when co-varying these results with socio-economic status and parental attitude to music data which was also gathered during this investigation.

Although the small n in this pilot study reduces statistical powers, the findings suggest an advantage for those having extra musical training in several areas after only one year. Naturally, individual differences are likely to be dependent on instrument choice, teacher relationship and intensity of practice. However, there appears to be an overall effect that musical training enhances aiming and catching abilities as one aspect of transferable visuo-spatial skills.

Secondly, the greater increases for children who had more music lessons, in comparison with those receiving statutory musical lessons, for the matrix reasoning supports previous findings (see e.g. Forgeard et al, 2008) regarding an advantage for musical training with nonverbal and spatial reasoning. The significance of these findings is that advantage is apparent after only one year of training, approximately 14 hours on average.

The marked difference in direction (see Figure 5) between the MMG and LMG with forwards and backwards digit span (BDS) demands further investigation, for if BDS is accepted as a measure of the active capacity of the central executive part of the working memory (Saito & Miyake, 2004), then this difference may point to a crucial developmental shift in line with Lee et al (2007) findings regarding the posited central executive, yet preceding their trained participants by five years.

However, we acknowledge that the study of transfer skills is not without contention (Postman, 1971; Halpern, 1998 & Barnett & Ceci, 2002), and although we have attempted to address some of the methodological issues surrounding the ‘unresolved mystery’ of far transfer effects (Jaschke et al, 2013) we also accede the limitations of this study. Conducting research in school environments is often confounded (Mitchell & Jolley, 2012). For example, break time bells rendered our test of phonological processing null and void and the Beery triumvirate of tests did not withstand large group settings as circumstances necessitated. Nevertheless, these initial findings, together with our other nested study which reveals a further advantage of musical training expressed as self-regulation of behaviour (observed by parents and teachers - see Rose et al, 2015 in press) suggests some further areas of early advantage associated with musical training. These findings contribute to our understanding of, and are in line with other research showing architectural change over time associated with specialist skill musical training (Norton et al, 2005; Wan & Schlaug, 2010).

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