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How learning a musical instrument affects the development of skills[☆]

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Abstract

Despite numerous studies on skill development, we know little about the causal effects of music training on cognitive and non-cognitive skills. This study examines how long-term music training during childhood and youth affects the development of cognitive skills, school grades, personality, time use and ambition using representative data from the German Socio-Economic Panel (SOEP). Our findings suggest that adolescents with music training have better cognitive skills and school grades and are more conscientious, open and ambitious. These effects do not differ by socio-economic status. Music improves cognitive and non-cognitive skills more than twice as much as sports, theater or dance. In order to address the non-random selection into music training, we take into account detailed information on parents, which may determine both the decision to pursue music lessons and educational outcomes: socio-economic background, personality, involvement with the child's school, and taste for the arts. In addition, we control for the predicted probability to give up music before age 17 as well as the adolescent's secondary school type. We provide evidence that our results are robust to both reverse causality and the existence of partly treated individuals in the control group.

JEL classification: I21, J24, Z11

Keywords: Music, cognitive and non-cognitive skills, educational achievement, SOEP

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1. Introduction

Publicly subsidized projects offering extracurricular music lessons are increasingly popular among policy makers. Having originated in Venezuela with the famous *El Sistema* (FundaMusical, 2013), such projects exist in many countries today. In Germany, the Federal Ministry of Education has launched *Kultur macht stark* (Culture makes you strong), a new initiative with 50 million euros of funding per year (BMBF, 2012). On the regional level, the government of North Rhine-Westphalia provides annual support to the project *Jedem Kind ein Instrument* (An instrument for every child) in the amount of 10 million euros (MSW, 2007). As stated in their official descriptions, these projects aim to improve educational opportunities, in particular for disadvantaged children and youth (e.g. BMBF, 2013).

The aim of reducing inequalities in educational opportunity through social policies promoting music education implicitly relies on the assumption that music fosters the development of cognitive and non-cognitive skills. The importance of these skills for educational and labor market success has been widely recognized (e.g. Almlund et al., 2011; Heckman and Kautz, 2012; Heckman et al., 2006; Heineck and Anger, 2010). According to findings on the "technology of skill formation", skills developed at younger ages promote later skill attainment (Cunha and Heckman, 2007; Cunha et al., 2010). In particular, the productivity of investments in subsequent stages increases as a result of previously acquired skills. Moreover, sociologists highlight that cultural capital – the familiarity with the codes and modes of conduct of particular social environments – influences success in education and the labor market (Bourdieu and Passeron, 1990; Lareau and Weininger, 2003; Lareau, 2011) and works as a mechanism for the reproduction of social inequality.

Numerous studies argue that music affects a variety of indicators of skill development (a summary can be found in Rickard et al., 2012). They argue that music induces brain reactions that stimulate the development of cognitive skills (Schellenberg, 2011). Moreover, both cognitive skills and school grades may be improved through the influence of music education on personality traits such as conscientiousness, openness, and perceived control (Schumacher, 2009). A positive effect on the latter may also lead the musically trained to be more ambitious. Lareau (2011) highlights the fact that music practice, similar to other extracurricular activities, enhances educational success by sending positive signals to school teachers and by fostering children's acquisition of some elements of cultural capital. In addition, when carried out in a group, music education can promote the development of social skills as well as the sense of belonging to a group. Finally, music – like other extracurricular activities – consumes time, which is then no longer available for other potentially beneficial or harmful activities (Felfe et al., 2011). Of course, extracurricular activities other than music can influence some of these outcomes similarly or even more effectively. Part of the challenge is to distinguish their differential effect.

The assumed positive effects of music training, which even motivate social policy-makers, stand in contrast to a lack of causal research on this topic. Observational studies on the effects of music education face the difficulty that the decision to learn a musical instrument is not made randomly. Causal studies must distinguish the effect of music from outcome differences related to observed and unobserved background characteristics. So far, only a small number of

experimental studies are able to identify true causal effects. For example, Schellenberg (2004) finds that music lessons enhance general intelligence of children, but do not affect their social skills. However, his study participants received music lessons for one year only.

This paper examines the effects of learning a musical instrument during childhood and adolescence on the development of cognitive and non-cognitive skills. We investigate the effect of long-term music training by restricting the treatment group to those who have received music lesson outside of school at least from age 8 to 17. Outcomes are measured at age 17 and include cognitive skills, school marks, personality traits (conscientiousness, openness, agreeableness, and perceived control), time use, ambition and optimism about future success.

We address the non-random selection into music practice by controlling for a large number of parental background characteristics: Parental income and education, household composition, the parents' personality and school involvement as well as the parents' taste for the arts. We take these variables into account using propensity score matching. In additional robustness checks, we also control for the predicted probability to give up music practice before age 17 as well as the type of secondary school which the adolescent attends.

Our findings suggest that learning a musical instrument during childhood and adolescence increases cognitive skills by one fourth and school grades by one sixth of a standard deviation. Moreover, adolescents with music training are more conscientious, open and ambitious. Differences by socio-economic status are small. The effects of music are much larger than those of alternative activities such as sports, theater and dance. For example, the effect of music on cognitive skills is more than twice as large as the effect of sports, an activity which has been found an important input for skill development (Barron et al., 2000; Felfe et al., 2011; Pfeifer and Cornelissen, 2010; Stevenson, 2010). Our estimates on the effects of sports are consistent with previous findings.

With this paper, we make six contributions to the literature. First, our study approaches causality better than previous observational studies. While we cannot entirely exclude the possibility that unobserved confounders drive our results, we account for more background characteristics than others have done before. Moreover, we take into account adolescents' secondary school type as well as their probability to give up music before age 17, which we can predict within a subsample. Our results are also robust to reverse causality and the existence of partly treated individuals in the control group.

Second, we use representative data for Germany to investigate our research question. This makes our results more generalizable than the experimental work which has been carried out so far. In particular, we are the first to use the German Socio-Economic Panel (SOEP) to study this question, which contains parental background information even from when the adolescent was still a child.

Third, our study examines the effects of music on more outcomes than previous studies have looked at. In addition to cognitive an non-cognitive skills, we observe school marks, time use and ambition.

Fourth, contrary to previous observational and experimental studies in this field, we examine the effects of long-term exposure to music. We investigate the development of skills among adolescents who have taken instrumental music lessons at least from age 8 to 17.

Fifth, we examine the heterogeneity of the effect with respect to socio-economic status. So-

cial policies promoting music education can only be effective if their treatment not only affects those from higher socio-economic backgrounds, who are likely to be involved in education-oriented leisure activities in any case. Indeed, we find that the effects of our treatment do not differ by socio-economic status.

Finally, we compare the effect of music to the effect of alternative leisure activities such as sports and dance. In most previous studies on leisure activities, such distinctions are not explicitely made. We find that the effect of music is much stronger than that of sports or dance.

Next, we describe why learning a musical instrument might influence educational opportunities. After a short summary of data and methodology, we present our findings. The study concludes with a discussion on the caveats of a causal interpretation of our results.

2. Hypotheses and previous literature

Numerous studies suggest that learning a musical instrument affects a variety of outcomes related to educational achievement (e.g., as summarized in Rickard et al., 2012). While most of these studies do not detect causal effects, they describe the mechanisms by which music could affect these outcomes. Discussing these mechanisms allows us to develop the hypotheses that will guide our empirical estimations.

The positive effect of music training on cognitive skills is the only effect which can be supported by previous causal evidence. In his experimental study, Schellenberg (2004) randomly assigned 132 children to three treatment groups. Each of them received piano, voice, or theater lessons for a year. Compared to both the theater and the control group, children receiving piano or voice lessons increased their IQ considerably. While Schellenberg's study participants are not a representative sample of all children, random allocation to treatments justifies a causal interpretation of his findings. Still, the question of what mechanism drives this effect remains open. Schellenberg (2011) considers three channels by which music potentially improves cognitive development. On the one hand, it might affect subdomains of cognitive functioning such as auditory temporal processing or visual memory. Alternatively, Schellenberg (2011) suggests that music training might affect intelligence by stimulating the executive function. The executive function represents judgment and problem-solving capacities, which are particularly malleable during childhood and correlated with IQ. However, his study does not confirm the executive function as a mediator of the effect of music on intelligence. As a third mechanism, Schellenberg (2011) considers that music may improve intelligence through its effect on non-cognitive skills or personality. In particular, studying a musical instrument requires regular training and thereby forces students to be self-disciplined, persistent, and involved (Covay and Carbonaro, 2010). As a consequence, this may improve conscientiousness, a dimension of the Big Five personality traits.

Other personality traits are likely to be affected by music as well. For example, we expect an effect on openness – another dimension of Big Five – given that children are regularly exposed to different types of music in music lessons than they usually listen to.[1]

[1]Some psychologists argue that personality is genetically determined and cannot be modified (Pervin et al.,

According to Schumacher (2009), learning a musical instrument improves the ability to judge one's understanding and progress. Musical performance in front of an audience allows the musician to verify whether or not she was able to interpret the piece correctly. Moreover, music lessons can teach children to judge their ability to learn as well as their progress in learning. Schumacher (2009) calls this ability a positive self-concept. Similarly, Covay and Carbonaro (2010) point out that learning a musical instrument teaches a child to handle success and failure. A possible way to measure these potential improvements is to examine how music affects perceived control. Perceived control indicates the extent to which someone believes that she or he can influence their own destiny.[2] If music training increases perceived control by improving the individual's judgement of his or her ability, success, and progress (Schumacher, 2009), we also expect these children to be more ambitious.

Intelligence, perceived control, and ambition are not the only reasons why adolescents with music training may be more successful in their educational achievement. Learning a musical instrument is also likely to send a positive signal to school teachers and potential employers (Spence, 1973). If a teacher knows about a student's after-school musical activities, that teacher may consider the student more competent than she or he actually is. This could lead the teacher to reward the perceived rather than proven competence with a better mark than actually appropriate. Indeed, in her qualitative study of children from different social backgrounds, Lareau (2011) reports that teachers listen more carefully to children talking about their organized free-time activities than to children talking about a game they played with neighbor children on the street. Such signaling effects are likely to translate into better marks, especially in more subjectively graded fields such as languages as well as in oral examinations, in contrast to in mathematics and written examinations (Andersen and Hansen, 2012). Similarly, being enrolled in music or other extracurricular activities provides a measurable advantage in job applications (Rivera, 2011).[3]

In addition to improvements in cognitive skills, the development of personality traits as

2005), but the personalities of children have been shown to be less stable than those of adults. Heckman and Kautz (2012) discuss the stability of personality traits and argue that conscientiousness tends to rise over the life cycle, citing examples of early childhood interventions in which personality was modified successfully, such as the Perry preschool project. Heckman and Kautz (2012) highlight that the long-lasting positive effect of these programs was attained through the program's positive impact on personality. Non-cognitive skills have proven to be particularly malleable at younger ages (Specht et al., 2011; Cobb-Clark and Schurer, 2012; Donnellan and Lucas, 2008). Hence, interventions like practicing a musical instrument may potentially also contribute to child development. Contrary to the Big Five personality measures, perceived control can be considered as modifiable over time (Cobb-Clark and Schurer, 2012).

[2]While the development of a positive self-concept might increase one's perceived control, learning a musical instrument might also be correlated with lower perceived control. Children learning a musical instrument often come from families in which parents intervene strongly into their children's schedules and choices of free-time activities (Lareau, 2011). Hence, a potential positive effect on perceived control might be hidden due to a systematically lower level of perceived control among the non-random sample of children make music.

[3]According to Rivera (2011), in addition to being perceived as having superior social skills, job candidates who are involved in extracurricular activities are considered by potential employers to be more interesting than candidates without outside interests. Such candidates are believed to be more pleasant coworkers. Moreover, employees who are involved in other activities in their free time are assumed by employers to have superior time management skills and a higher work ethic.

well as favoritism due to signaling effects, learning a musical instrument may stimulate cultural capital. Cultural capital is the ability to be familiar with the codes and mods of conduct of a particular social environment. It is one of the important causes of social reproduction (Bourdieu and Passeron, 1990; Lareau and Weininger, 2003) and has important effects on educational achievement (Tramonte and Willms, 2010). Music training usually takes place alone or in a small group. More than in regular school classes, exclusive relations with as well as attention from the instructor teaches children and adolescents to interact with a person of authority. Besides learning to play their instrument, adolescents are likely to acquire the capacity to express their interests and rights in an adequate manner, a qualification which Lareau (2011) designates as "sense of entitlement".

Moreover, when music classes are taught in a group or an orchestra, students closely and directly interact with their peers. Typically, such interactions considerably differ from usual classroom interactions. On the one hand, students have to learn to take over someone else's perspective, putting their own interests back for the benefit of the common goal. With other words, they have to learn to see their fellow students as partners rather than competitors (Schumacher, 2009). On the other hand, in particular in projects proposing access to music education for all, children playing in a group learn to interact with fellow students coming from various social backgrounds (Covay and Carbonaro, 2010). In his experimental study, Schellenberg (2004) finds that music training does not improve social skills, while theater does. We approximate the measurement of improved social skills by examining the treatment effect on agreeableness.

Beyond these advantages in terms of skills and education, music training might enhance social well-being by giving individuals a sense of belonging to a group. In addition to physical well-being, Lindenberg (1989) and Ormel et al. (1999) consider social well-being as a dimension that human beings aim to maximize. It consists of three facets: status, behavioral confirmation, and affection. Music education could play a role in status attainment. According to Ormel et al. (1999), the status is the relative ranking compared to other people. It is attained, for example, through "occupation, life style, [and] excellence in sports" (Ormel et al., 1999, p. 67). Not only sports, but also playing a musical instrument could therefore contribute to higher status attainment. Contrary to the previously discussed external signal, which serves as an indicator of higher skills to other people, playing a musical instrument signals affiliation to a particular social group and thereby raises the well-being of the individual him- or herself. Indeed, Menninghaus (2011) relates participation in the arts to the costly signal theory. He states that the possession of artistic objects or engagement in cultural activities are used to signal one's affiliation to a certain social status. Menninghaus (2011) highlights parallels between such a costly signal and an evolutionary interpretation of the role of the arts for human societies.

Finally, learning a musical instrument could influence educational achievement through its effect on time use. Three arguments are conceivable. First, musical practice might enhance school performance, because the use of free time to play an instrument reduces the time available for potentially less productive activities such as watching TV. Second, time spent learning an instrument is time which is no longer available for studying, such that music practice could have a negative effect on school performance (Felfe et al., 2011). Third, as Lareau (2011) argues, children participating in extracurricular activities learn to better manage their learning

Table 1 – *Hypotheses: Potential effects of music training*

Hypothesis	**Mechanism**
Cognitive skills	
→ Improved cognitive skills	Influence on subdomains of cognitive function, executive function or via non-cognitive skills (Schellenberg, 2004, 2011)
Non-cognitive skills	
→ Increased conscientiousness	Music requires self-discipline (Schumacher, 2009)
→ Higher perceived control	Judge ability, develop positive self-concept (Schumacher, 2009)
→ Increased openness	Contact with classical music
→ Increased ambition	Judge own ability, success and progress (Schumacher, 2009)
School achievement	
→ Improved school grades	Positive signal to school teachers (Lareau, 2011), improved cognitive skills
Cultural and social capital	
→ Enhanced cultural capital	Interaction with teacher in small group (Lareau, 2011)
→ Improved social skills	Interaction with peers and teachers (Schumacher, 2009)
→ Higher social well-being	Belonging to a group (Ormel et al., 1999; Menninghaus, 2011)
Time use	
→ Changes in time use	Crowding out of positive or negative activities (Felfe et al., 2011), structure learning and time schedule (Lareau, 2011)
Inequality	
→ Stronger effects for low SES	Efficiency of investment (Heckman and Masterov, 2007), cultural mobility (DiMaggio, 1982)
→ Stronger effects for high SES	Cultural reproduction (Bourdieu, 1986)

processes and time schedules. Hence, study time could be used more efficiently and therefore school performance might improve even though less time is available for studying.

Estimating the mean effect of learning a musical instrument might hide important heterogeneities. Policies such as those mentioned above are aimed primarily at children from disadvantaged social backgrounds. Heckman and Masterov (2007) point out that investments in children from families with a lower socio-economic status are among the rare policies that do not involve a trade-off between efficiency and fairness. In the same sense, DiMaggio's (1982) cultural mobility hypothesis suggests that children from disadvantaged social backgrounds benefit particularly from music education, because these have a higher potential benefit from such education as a form of compensation for missing educational inputs from the children's families. In contrast, Bourdieu's (1986) cultural reproduction hypothesis argues that richer and more educated parents have access to better quality extracurricular activities, which stimulate skill development more successfully.

Besides understanding the effects of leisure activities on skill development, further research is needed to understand the extent to which these activities can act as substitutes. Some of the abovementioned effects are likely to result from extracurricular activities other than music as well. Several studies show the benefits of athletic participation during youth (Barron et al.,

2000; Felfe et al., 2011; Pfeifer and Cornelissen, 2010; Stevenson, 2010). Schellenberg (2004) does not detect improvements in cognitive skills among individuals with theater lessons. Covay and Carbonaro (2010) study the general effects of extracurricular activities based on the assumption that all such activities contribute to the development of cognitive and non-cognitive skills. In this paper, we give evidence on differential effects by comparing music to sports, theater and dance, as described below.

3. Data

The German Socio-Economic Panel study (SOEP) is to our knowledge currently the best available longitudinal data set for studying the effects of learning a musical instrument. First, it contains a detailed assessment of the intensity and duration of music activities for representative youth cohorts (Schupp and Herrmann, 2009). Second, the SOEP measures a large variety of outcomes such as school results, cognitive skills, personality, time use, and ambition. Third, given that it is a household rather than an individual survey, the SOEP allows us to directly observe numerous parental background characteristics (Wagner et al., 2007). In particular, we are able to measure the parents' socio-economic background, personality, involvement in the child's school success, leisure time use as well as taste for the arts. Moreover, due to the longitudinal nature of the survey, these variables are available for when the adolescent was still a child.

The SOEP contains a detailed assessment of music activities during youth. At the age of 17, young adults answer the following five questions (Weinhardt and Schupp, 2011):

⇒ Do you play a musical instrument or pursue singing seriously? (Yes or no)

If the answer is yes, the following further questions are asked:

1. What type of music do you make? (Classical, Pop/Rock/etc or Folk music)
2. Do you do this alone or in some sort of group? (Alone/with teacher, in an orchestra/choir, in a band or in another type of group)
3. How old were you when you started? (Age)
4. Do you take or have you ever taken music lessons outside of school? (Yes or no)

With these answers, it is possible to construct a variety of treatment indicators. In our main specification, we consider those individuals to be musically active who have played a musical instrument at least between age 8 and 17, and who take music lessons outside of school. Thus, rather than simply studying adolescents who claim to be active in music, we make additional requirements on duration and intensity. This allows us to examine the effect of long-term exposure to music training. Moreover, at the age of 8 the decision to take up music lessons is strongly influenced by the parents, for whom we observe a large number of background characteristics. Finally, taking lessons outside of school is an indicator of a more serious involvement with the activity, because it excludes those who make music only occasionally.

The only other extracurricular activity which is assessed in similar detail in the SOEP Youth Questionnaire is sports. This will allow us to compare our results to the alternative treatment

of doing sports regularly. For further activities, we only know the frequency with which they are carried out. In particular, we will compare the effects of music training to the effects of playing theatre or dancing at least weekly.

All outcomes examined in this study were taken from the SOEP Youth Questionnaire as well and are thus measured at the age of 17. In particular, we examine the effect of music training on cognitive skills, school grades, personality, ambitions and time use.

Cognitive skills have been measured since 2006 with a standardized test. This test consists of three subscores: analogies, figures, and mathematics operators (Schupp and Herrmann, 2009). Good verbal knowledge is indicated by high scores for Analogies, where respondents have to identify correct word pairs. To get a good score in Figures, respondents have to identify the correct symbol continuing a given row of symbols. Similarly, the test of mathematics ability requires individuals to insert operators in incomplete mathematical computations. In order to facilitate the interpretation of cognitive skills, all results were normalized. Please refer to Table A.6 in the appendix for more details on these assessments.

In addition to directly testing their cognitive skills, the SOEP Youth Questionnaire asks young adults about their latest school grades in German, mathematics, and their first foreign language. Due to fundamental differences in educational programs, grades are not easily comparable between the three German secondary school types (Hauptschule, Realschule, Gymnasium). To facilitate comparisons, we normalize all school grades within each type of secondary school.

The SOEP Youth Questionnaire investigates various dimensions of personality using simplified psychologically validated items to which respondents state their level of agreement on a Likert scale. For our study, conscientiousness, openness, and agreeableness – three dimensions of the Big Five personality traits (McCrae and Costa, 1999; Lang et al., 2011) – seem particularly interesting. Moreover, our hypotheses suggest that practicing a musical instrument may affect perceived control. Someone is characterized by a high level of perceived control if she or he believes to be able to influence their own destiny (Specht et al., 2013). For each dimension, we use the average answer among all items. For detailed descriptions of the items, please refer to Table A.6 in the appendix.

In addition to assessing current skills and personality, the SOEP Youth Questionnaire asks young adults about their plans and worries for the future. In this study, we are interested in the young adult's plans to obtain an upper secondary school degree (Abitur) as well as a university degree. Moreover, respondents are asked to estimate the probabilities to find a job in their desired occupation and to be successful in their job. In order to be able to interpret the magnitude of potential effects, we normalize these estimated probabilities.

Finally, a measure indicating whether the individual watches TV and reads daily will allow us to examine how learning a musical instrument affects the adolescent's use of leisure time.

Due to its longitudinal nature and household dimension, the SOEP contains rich background information on each adolescent's family as well as information on the individual's childhood. This is important because families with children who learn a musical instrument differ strongly from others. In addition to the standard socio-economic characteristics of the parents such as education, income, and household composition, we observe some important aspects that are likely to influence the decision to enroll the child into music lessons. In particular,

Table 2 – *Sample size by treatment status*

	Treatment		Control		Total	
	Nb	%	Nb	%	Nb	%
Main sample[1]						
All	372	11.0	2,997	89.0	3,369	100.0
Girls	238	14.3	1,430	85.7	1,668	100.0
Boys	134	7.9	1,567	92.1	1,701	100.0
Low and medium socio-economic status (SES)	102	5.4	1,783	94.6	1,885	100.0
High socio-economic status (SES)	270	18.2	1,214	81.8	1,484	100.0
Sample for cognitive skills[1]						
All	212	11.8	1,587	88.2	1,799	100.0
Girls	135	15.7	723	84.3	858	100.0
Boys	77	8.2	864	91.8	941	100.0
Low and medium socio-economic status (SES)	62	6.2	936	93.8	998	100.0
High socio-economic status (SES)	150	18.7	651	81.3	801	100.0
Sample for Big 5 personality traits[1]						
All	230	13.0	1,541	87.0	1,771	100.0
Girls	136	16.1	709	83.9	845	100.0
Boys	94	10.2	832	89.8	926	100.0
Low and medium socio-economic status (SES)	69	7.1	909	92.9	978	100.0
High socio-economic status	161	20.3	632	79.7	793	100.0

[1] The main sample was used to examine the effects of music training on school grades, perceived control, time use, and ambition. Sample sizes are smaller for cognitive skills and the Big 5 personality traits as these outcomes were only measured since 2006.

Source: SOEP v29 (2001-2012 pooled), own calculations. Definition of treatment: Have music lessons at least between age 8 and 17. Definition socio-economic status: Low SES: Mother has medium secondary school degree or less, High SES: Mother has upper secondary school or university degree.

our data contain the parents' personality, involvement in the child's education as well as taste for the arts. For all parental variables, we use observations on the mother. If not available, we replace them with those for the father. Time-varying variables were measured when the child was aged 5 or, if not available, as early as possible.[4] Please refer to Table A.7 in the annex for a list of available control variables and when they were observed.

If we consider only individuals with no missing values on any treatment or control variable, we obtain a final sample of 3,369 observations out of the 3,954 who answered the SOEP Youth Questionnaire.[5] 372 of these were active in music according to our definition, which is that they took music lessons between the ages of 8 and 17. As Table 2 indicates, the share of children learning a musical instrument is considerably higher among girls and among children from high socio-economic status. Table 2 also shows that the sample is considerably smaller for cognitive skills and the Big Five personality traits. The reason is that these outcomes were measured only since 2006.

[4] About 60 percent of our sample entered the data after age 5 of the child. On average, individuals enter our sample when they are 8.2 years old. 53 percent of all treated enter the SOEP no more than three years after the start of the treatment.

[5] Out of the 585 observations with missing values, we lose only 169 due to missing values on the covariates. The other 416 observations are lost due to missings on the outcomes. The outcomes with by far the highest number of missings (about 170 each) are the foreign language mark and perceived control.

Table 3 – *T-test of differences in background characteristics between adolescents with and without music training*

	Treatment	Control	Difference/Std error
Parents' socio-economic status			
Monthly HH net income	3519	2491	1028*** (92)
University degree	0.63	0.28	0.35*** (0.02)
Parent with lower secondary school degree	0.23	0.43	-0.20*** (0.03)
Mother (father) has no degree	0.06	0.17	-0.11*** (0.02)
Vocational degree	0.64	0.70	-0.06** (0.03)
Migration background	0.10	0.19	-0.08*** (0.02)
Girl	0.64	0.48	0.16*** (0.03)
Oldest child in family	0.47	0.51	-0.05* (0.03)
Number of siblings	1.48	1.45	0.03 (0.06)
Rooms per person	1.28	1.12	0.15*** (0.02)
Rural area	0.20	0.26	-0.06** (0.02)
Parents' taste for the arts			
No cultural events	0.14	0.40	-0.26*** (0.03)
Monthly cultural events	0.27	0.10	0.17*** (0.02)
No artistic activities	0.33	0.58	-0.26*** (0.03)
Monthly artistic activities	0.35	0.18	0.18*** (0.02)
Appreciation for art (parents)	0.71	0.62	0.09*** (0.01)
Parents' involvement with school			
Parents care strongly about school achievement	0.26	0.25	0.01 (0.02)
Parents don't support learning	0.19	0.23	-0.04 (0.02)
Conflict with parents due to school results	0.48	0.55	-0.07*** (0.03)
Parents go to parent-teacher meeting	0.82	0.73	0.08*** (0.02)
Parents go to teacher's consultation hours	0.57	0.57	-0.00 (0.03)
Parents actively contact school teachers	0.25	0.22	0.04 (0.02)
Parents engage as parent representatives	0.32	0.15	0.17*** (0.02)
Parents don't engage with the child's school	0.06	0.10	-0.04** (0.02)
Parents' personality			
Conscientiousnes	0.86	0.87	-0.01** (0.01)
Extraversion	0.72	0.72	-0.00 (0.01)
Agreeableness	0.80	0.81	-0.01 (0.01)
Openness	0.69	0.65	0.03*** (0.01)
Neuroticism	0.58	0.59	-0.01 (0.01)
Number of observations	3369		

Source: SOEP v29 (2001-2012 pooled), own calculations. T-test of background characteristics between treatment and control group for the main sample. These differences are similar for the alternative samples used for cognitive skills and the Big Five personality traits (see Table 2), which can be provided by the authors on request. Definition of Treatment: Have music lessons at least between age 8 and 17. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 shows that children who have learned a musical instrument differ strongly in almost all parental background characteristics from those who have not. Parents of the former earn more, are more educated, and are in closer contact with their child's school. Unsurprisingly, parents of musically active children also have a stronger taste for arts. They do not differ from other parents in personality traits, however.

4. Method

The decision to learn a musical instrument at age 8 or before is not made randomly. Given that we do not observe an exogenous variation in music lesson enrollment, our estimation relies on the conditional independence assumption. To estimate the effect of music on skill production, we assume that the decision to learn a musical instrument is uncorrelated with any unobserved characteristics which also have an influence on the development of skills, to the extent that they are uncorrelated with the observable characteristics we control for.

We estimate the effect of learning a musical instrument at least from age 8 to 17. Non-random selection into the treatment takes place at two stages. The decision to take up music lessons at an early age is likely to be strongly influenced by the parents. Therefore, our main specification takes into account a large number of parental background characteristics, which were measured when the adolescent was still young. Moreover, the likelihood to carry on music practice until the age of 17 might depend on further individual characteristics. In the sensitivity tests presented in Section 6, we deal with this second stage of selection by including the predicted probability to give up music as well as secondary school type as additional control (or mediator) variables.

We apply propensity score matching to account for the non-random decision to learn a musical instrument. The estimator was implemented in the following way. First, we estimate the probability of learning a musical instrument with a probit model. This probability is called the propensity score. Ideally, all variables influencing the decision to enroll in music lessons should be included in the selection model. Such a decision may be motivated by utility and taste. In addition to the direct utility or pleasure someone derives from making music, parents are likely to consider music training as an investment in their child's future success (Eide and Ronan, 2001; Lareau, 2011). Moreover, parents might enroll their child in music lessons because their own previous experience or habit of arts consumption has led them to develop a taste for the arts, as postulated in the learning-by-consuming approach (Garboua and Montmarquette, 1996). A preference for the arts also depends on the educational level if we assume that more highly educated people are more able to appreciate artistic production and consumption (Lunn and Kelly, 2009). Finally, more highly educated parents might be more likely to enroll their children in music lessons, because the artistic activities available to children are adapted to the tastes of the more highly educated (Lunn and Kelly, 2009).

In our selection model, we address these various motives in the following way. First, both utility-based and taste-based motivations are related to socio-economic status (Yaish and Katz-Gerro, 2012). We therefore control for parental education, qualifications, and nationality as well as household net income and the mother's age at birth. These variables are observed be-

fore the start of music training, when the child is aged five.[6] In addition, we include variables approximating the complications involved in enrolling a child in music lessons: the number of rooms per person at home and whether the household lives in a rural area. Moreover, parents are more likely to consider music lessons as an investment in children's future skills if they are more involved with the child's school activities in general. Therefore, we control for parents' contact with their child's school, which is approximated by the parents' disposition to help with homework, regularly meet the teacher, or be involved with the child's schooling in other ways.[7] Furthermore, the parents' personalities might play a role in their eagerness to invest in their child's skill development. To complete the selection model, we controlled for gender[8] and include sample[9], federal state, and birth-year fixed effects.

A table with all coefficients in the selection model can be found in the appendix (Table A.8). Overall, the selection model is able to explain about 20 percent of the variation in music practice, a share comparable to similar studies (for example Felfe et al., 2011). The coefficients are not surprising: Given that many of the characteristics explaining selection into music practice are correlated with each other, some of them are not statistically significant. According to recommendations from the statistics literature (Stuart, 2010), we include these insignificant coefficients in the selection model, as the aim is not to find the best model explaining the treatment but to balance observable (and if possible unobservable) characteristics in the treatment and control groups as much as possible.

Figure A.1 in the appendix shows common support between the treatment and control groups. The graphs indicate that untreated individuals (children who do not learn a musical instrument) are more likely to have a low propensity score, a further indicator that our selection model predicts musical practice quite well. Still, for the majority of the distribution, it is possible to find at least one corresponding control observation for each treated individual. With a caliper of 1 percent, only 3 out of 372 individuals in the treatment group and none in the control group remain unmatched.[10]

Once the propensity score is estimated and we have checked the degree of common support, we find matches in the control group for each treated individual. We use radius matching with a caliper of one percent, meaning that we give equal weight to each control observation having a propensity score in the range of one percent around the corresponding treated observation. The equal weights of the control observations being matched to one treated observation are chosen to sum to one.

[6] About 60 percent of all observations entered our data at a later age. For them, we measure parental background characteristics in the year of entry into the data. On average, the individuals of our sample enter the data when they are 8.2 years old.

[7] These variables were not observed when the child was young, but retrospectively reported by the adolescent herself at age 16. We cannot exclude the possibility that they are influenced by the treatment.

[8] Ideally, the selection model as well as the matching would be conducted separately for boys and girls. Unfortunately, reducing our sample by half would considerably reduce the match quality.

[9] The SOEP consists of several samples that were added over time in order to increase the overall sample size of the SOEP. In some of these samples, parts of the population were overrepresented (foreigners, families with many children, or high-income families).

[10] For the other samples, these numbers are: 7 out of 205 treated individuals (cognitive skills sample). 7 out of 223 individuals (Big 5 personality traits sample). See Table A.9 in the appendix.

After matching, we can check whether the covariates are balanced between the treatment and control groups. Table A.10 in the appendix shows that this is the case.

After adjustment by matching, we obtain the correlation between music practice and cognitive and non-cognitive skills in a weighted least squares regression. If our selection model is able to control for all relevant variables, we estimate the average treatment effect on the treated (ATT) (Imbens and Wooldridge, 2008). Algebraically, the average treatment effect on the treated is:

$$A\hat{T}T = \frac{1}{N_T}\sum_{i=1}^{N_T} T_i y_i - \frac{1}{N_C}\sum_{i=1}^{N_C}(1-T_i)\,\hat{w}_i y_i \tag{1}$$

where N_T and N_C are the number of treated and control observations, T_i is the treatment indicator, and y_i the outcome for individual i. Control observations are weighted with weight $\hat{w}_i$, which is obtained from matching as described above. Standard errors are estimated by bootstrap with 1999 replications.[11]

While similar results can be obtained with a simple linear regression model, propensity score matching has three advantages in our context. First, it allows us to use a large number of control variables even with a limited sample size, given that these control variables are summarized in the propensity score (Huber et al., 2013). Second, contrary to ordinary least squares, we do not need to assume a linear relation between music training and outcomes. Finally, in a setting where children learning a musical instrument are likely to have a significantly different family background than other children, the necessity to verify the existence of common support will provide us with some hint as to the comparability of treatment and control group (Imbens and Wooldridge, 2008). Given that our control group is ten times as large as the treatment group, we can find high-quality matches for most treatment observations.

Under the assumption of conditional independence, we can interpret the correlation between music and skills obtained with the matching estimator as a causal consequence of music practice (Imbens and Wooldridge, 2008). Given that we find matches in the control group for each treated observation, we estimate the average treatment effect on the treated. To obtain the average treatment effect, it would be necessary to separately estimate the average treatment effect on the non-treated by finding matches in the treatment group for each control observation. As the treatment group is ten times smaller than the control group, the quality of such matches would be low. To obtain robust results, we restrict our analysis to the average treatment effect on the treated.

5. Results

Table 4 shows outcome differences at age 17 between adolescents with and without music training. Differences are estimated applying propensity score matching to control for a large number of observed individual and family characteristics. We control for socio-economic background, the parents' personality, involvement with the child's school success, and taste for the arts.[12] The treatment is defined as having played a musical instrument from at least the age

[11] An analytical approximation would be possible, but is not recommended by Huber et al. (2012).

[12] An overview of all control variables can be found in Table A.7 in the appendix.

Table 4 – *Outcome differences between adolescents with and without music training or alternative activities*

	Effects of music training from age 8 to 17				Effects of alternative activities		
		Differences by socio-economic status (SES)			Sports	Dance	
	Full sample (1)	*Low SES* (2)	*High SES* (3)	*Difference* (4)	*Full sample* (5)	*Full sample* (6)	*Sample size*
Cognitive skills							
Average cognitive skills	0.24*** (0.08)	0.20 (0.14)	0.24** (0.10)	0.04 (0.17)	0.11 (0.07)	0.08 (0.06)	1,772
Analogies	0.28*** (0.09)	0.23 (0.14)	0.29** (0.11)	0.05 (0.19)	0.04 (0.07)	0.05 (0.06)	1,772
Figures	0.19** (0.09)	0.19 (0.13)	0.18 (0.11)	-0.02 (0.17)	0.04 (0.07)	0.06 (0.06)	1,772
Maths operators	0.11 (0.09)	0.07 (0.15)	0.12 (0.11)	0.05 (0.18)	0.15** (0.07)	0.07 (0.06)	1,772
School achievement[1]							
Average school grade	-0.17*** (0.06)	-0.17 (0.11)	-0.16** (0.08)	0.01 (0.14)	0.02 (0.05)	-0.05 (0.05)	3,364
German grade	-0.16** (0.06)	-0.11 (0.11)	-0.17** (0.07)	-0.06 (0.14)	0.04 (0.05)	-0.02 (0.05)	3,364
Foreign language grade	-0.14** (0.06)	-0.10 (0.11)	-0.15^{+} (0.08)	-0.05 (0.14)	0.10^{+} (0.05)	-0.01 (0.05)	3,364
Mathematics grade	-0.09 (0.07)	-0.17 (0.12)	-0.06 (0.08)	0.11 (0.15)	-0.08 (0.05)	-0.06 (0.05)	3,364
Personality							
Conscientiousness	0.28*** (0.09)	0.21 (0.15)	0.31*** (0.12)	0.10 (0.20)	-0.02 (0.07)	0.09 (0.07)	1,753
Openness	0.33*** (0.09)	0.39*** (0.14)	0.29** (0.12)	-0.10 (0.19)	-0.10 (0.07)	0.20*** (0.06)	1,753
Agreeableness	0.18^{+} (0.09)	0.19 (0.14)	0.17 (0.12)	-0.02 (0.18)	0.02 (0.07)	-0.09 (0.06)	1,753
Perceived control	0.07 (0.06)	0.16 (0.11)	0.03 (0.07)	-0.13 (0.14)	0.05 (0.05)	0.20*** (0.05)	3,364
Time use							
Watch TV daily	-0.13*** (0.03)	-0.09^{+} (0.05)	-0.14*** (0.04)	-0.05 (0.06)	0.01 (0.02)	-0.03 (0.02)	3,364
Read books daily	0.08** (0.03)	0.07 (0.05)	0.08^{+} (0.04)	0.02 (0.07)	-0.02 (0.02)	-0.04^{+} (0.02)	3,364
Ambition							
Aim Abitur	0.15*** (0.03)	0.21*** (0.05)	0.11*** (0.03)	-0.10 (0.06)	0.05** (0.02)	0.05** (0.02)	3,364
Aim university	0.18*** (0.03)	0.21*** (0.06)	0.16*** (0.04)	-0.06 (0.07)	0.04^{+} (0.02)	0.07*** (0.02)	3,364
Job success likely	0.07 (0.06)	0.08 (0.10)	0.06 (0.07)	-0.02 (0.12)	0.16*** (0.05)	0.14*** (0.05)	3,364
Desired profession likely	0.07 (0.06)	0.17^{+} (0.10)	0.03 (0.07)	-0.14 (0.12)	0.14*** (0.05)	0.09^{+} (0.05)	3,364

[1] Note that in Germany, better performance is rewarded with a lower school grade.

Source: SOEP v29 (2001-2012), own calculations. Column (1) shows the baseline results for the full sample. Columns (2) to (4) show differential effects by socio-economic status. Low SES: Mother has medium secondary school degree or less, High SES: Mother has upper secondary school or university degree. Colums (5) and (6) show the effect of alternative activities: Sports (since age 8 including the participation in competitions) and Dance (weekly). Propensity score matching is used to account for control variables (radius matching with caliper 0.01). The sample size is smaller for cognitive skills and some personality measures, as these have only been assessed since 2006. Standard errors in parentheses are clustered at the household level and estimated by bootstrap (1999 replications). Significance levels: $^{+}$ $p < 0.1$ ∗∗ $p < 0.05$ ∗∗∗ $p < 0.01$

of 8 to 17 and having taken music lessons outside of school. Our data allow us to consider as treated only those who have played music for a minimum number of nine years. We choose this restriction because we are interested in the long-term effects of music training. Implications of the treatment definition for a causal interpretation of our results are discussed in Section 6.

In each row, we estimate the effect of music on a different outcome. Outcomes are grouped into five categories: cognitive skills, school achievement, personality, time use and ambition. Differences in cognitive skills, school grades, personality, and optimism about future professional success are measured in terms of standard deviations. Differences in time use and educational ambition (whether the individual aims a higher secondary school or university degree) are stated in percentage points.[13]

Each column corresponds to a different set of estimations, which we discuss in the following. Column (1) represents the baseline specification. Here we examine outcome differences between adolescents with and without music training for the entire sample. The results indicate that a substantial part of these differences remain unexplained even after controlling for a large number of covariates. We can see that in the cognitive test, children who learned a musical instrument scored on average one fourth of a standard deviation higher than other children. This is more than twice the effect Felfe et al. (2011) found for sports participation. The difference is driven in particular by higher scores for word analogies and figures. Hence, verbal and spatial skills are possibly more strongly affected than mathematical abilities. In addition to advantages in cognitive skills, school grades of adolescents with music training are one sixth of a standard deviation above those of other students. Note that in Germany, the grading scale runs from 1 (highest possible score) to 6 (failing).

With respect to personality, adolescents with music training differ significantly as well. They are more than one fourth of a standard deviation more conscientious and open than others.[14] Learning a musical instrument is not associated with higher agreeableness. Finally, contrary to what one would expect, children who learn a musical instrument are not characterized by a higher perception of control.

If we look at time use and educational ambitions, we see systematic differences between the two groups as well. Children who learn a musical instrument are 13 percent less likely to watch TV every day. Moreover, they are 15 percent more likely to plan on obtaining an upper secondary school degree (Abitur) and 18 percent more likely to aim at attending university.

In the next step, we examine the heterogeneity of these outcome differences with respect to socio-economic background. We differentiate socio-economic background according to parental education, given that education is an important determinant of cultural taste (Lunn and Kelly, 2009) and correlated with income. We consider parents who have either no or up to a medium secondary school degree (Hauptschule or Realschule) as belonging to the lower socio-economic status group. Conversely, parents with either an upper secondary school or university degree are considered as having a higher socio-economic status. According to this definition, our sample contains 1885 individuals with low and 1484 individuals with high socio-

[13] Please refer to Table A.6 in the appendix for more details on the outcomes.

[14] The higher value for openness is at least partly related to the fact that one of the three items assessing openness deals with openness to artistic experiences.

economic status. Among the former, only 5.4 percent (102 adolescents) learn a musical instrument from age 8 to 17, while 18.2 percent (270 adolescents) of the latter group do so. Unfortunately it is not possible to further distinguish among children of low socio-economic status, because too few of them learn a musical instrument.

The effects of music training for adolescents of low and high socio-economic status, as well as the difference between these effects are shown in columns (2) to (4) of Table 4. Due to the small sample size, many coefficients in column (2) are not significant. Still, we observe that outcome differences between adolescents with and without music training are similar in magnitude, irrespective of socio-economic origin. The ambition to obtain an upper secondary school degree is the only outcome, which significantly differs between both socio-economic groups. The effect of music training on such ambitions is significant for all, but twice as large among adolescents of lower socio-economic status. Such a difference is not too surprising if we consider that already 66 percent of adolescents of high socio-economic status plan at attaining an upper secondary school degree, while only 31 percent of the other group does so. Hence, adolescents of lower socio-economic status have more to catch up.

An apparent question is whether the strong outcome differences between adolescents with and without music training are specific to music. With other words, do we observe similar outcome differences if we compare adolescents who engage in another type of leisure activity compared to those who do not? Columns (5) and (6) show that other activities can have positive effects as well, even though those of music training are likely to be stronger. We run the same estimations as the baseline specification presented in column (1) and replace music training from age 8 to 17 with alternative activities.

Column (5) shows the effects of being sporty, an activity which has been found beneficial in numerous studies.[15] In order to be comparable to music, we consider as treated those who have been sporty at least from age 8 to 17 and who have regularly participated in sports competitions. 507 individuals (15 percent) of our sample are active according to this definition. When it comes to cognitive skills, we approximately replicate the findings from Felfe et al. (2011). Sporty adolescents score about one tenth of a standard deviation higher, even though this result is not statistically significant in our analysis. Interestingly, the score in the maths operators test increases significantly due to sports participation, while it remained unchanged among those who are musically active. Moreover, sports does not seem to affect school marks and personality. We do, however, observe positive effects of sports on ambition. In particular, sporty adolescents are more optimistic about their future success, which was not the case for adolescents with music training.

In column (6), we investigate the outcome differences for individuals who play theater or dance at least weekly. This corresponds to 668 individuals (20 percent) of our sample.[16] According to our estimation, playing theater or dancing does not affect cognitive skills or school marks, a result which is in line with findings from Schellenberg (2004). However, dance and theater have strong effects on personality and ambition. If we can interpret our results as causal,

[15] See for example Felfe et al. (2011); Pfeifer and Cornelissen (2010); Barron et al. (2000); Stevenson (2010).

[16] Unfortunately, we cannot restrict this analysis to those individuals who have played theater or danced for a minimum number of years, as this information is not available in the SOEP.

playing theater and dancing increases openness and perceived control by one fifth, and conscientiousness by one ninth of a standard deviation. All four indicators of ambition moderately, but significantly increase as well.

The results presented in this section are robust to different treatment definitions, control variable specifications, and sample restrictions. For example, the results remain very similar if our treatment definition does not require a treated individual to take music lessons throughout the entire period from age 8 to 17. Including individuals who started music lessons at age 9 or 10 or even later does not fundamentally alter our results.[17] We consider the results for alternative activities presented in columns (5) and (6) as less reliable, given that control variables were specifically chosen to account for the non-random selection into music training. If the decision to engage in sports, theater and dance is determined by different factors, we might not sufficiently take them into account.

6. Discussion

Even after controlling for a large number of social background characteristics, we find strong differences in terms of cognitive and non-cognitive skills between adolescents who learned a musical instrument during childhood and those who did not. In order to interpret these differences as causal effects of music training, we must rely on the conditional independence assumption, exclude the possibility of reverse causality and make one further assumption on the existence of partly treated individuals in the control group. This section discusses these assumptions and the extent to which they are valid and can be tested.

Is the conditional independence assumption plausible? When applying propensity score matching, the average treatment effect on the treatment can be interpreted as a causal effect if the conditional independence assumption is valid. In this study, this means that given the control variables included in the selection model, enrollment in music lessons is as good as random. Such an assumption would be invalidated if unobserved characteristics influenced the decision to learn a musical instrument and also had an impact on the outcome variables of interest.

We define our treatment as learning a musical instrument at least from age 8 to 17. With this treatment definition, estimation biases resulting from selection into treatment can take place at two stages: The initial decision to take up music lessons and the decision not to give up until age 17.

We argue that our estimation satisfies the conditional independence assumption with respect to the initial decision to engage with music at age 8 or before. At such a young age, the choice of a long-term extracurricular activity such as music is strongly determined by the parents. For the parents, however, we observe a very large number of background characteristics,

[17] Furthermore, our results are not sensitive to minor modifications in the choice of control variables. In terms of the composition of the sample studied, we do not find different outcomes if we drop the observations of individuals who started their treatment later than age 8 instead of including them in the control group. Finally, our findings are robust to estimations within the subsample of individuals whose parents entered the SOEP before they actually started their music lessons.

in particular their socio-economic status, personality, involvement with their child's education, and taste for the arts. All of these observed characteristics are strongly correlated among each other and therefore also likely to be strongly correlated with any unobserved characteristics we might miss. The influence of unobserved characteristic invalidates a causal interpretation of our results only to the extent that these unobserved characteristics are uncorrelated with the observed characteristics we control for (Stuart, 2010).

The decision to continue learning a musical instrument until age 17 is more likely to be based on unobserved characteristics of the child.[18] To test the robustness of our estimates with respect to that second source of selection bias, we include two additional control variables.

First, we are able to estimate to probability to give up music training for a random subsample of 281 individuals. We can retrace the history of musical activities for these individuals back to age 12.[19] 50 of them (18 percent) played a musical instrument at age 12, but gave up before age 17. This is a large number, given that among the individuals of the subsample only 43 (15 percent) have learned a musical instrument according to our treatment definition from age 8 to 17. Using all covariates and outcome variables of our main analysis, we estimate the probability to belong to the group of those who gave up music training within the subsample with a probit model. With the coefficients resulting from this estimation, we predict this probability for the entire estimation sample.

Second, one of the most important predictors of educational achievement in Germany is the type of secondary school in which the child is enrolled. Whether the child goes to upper secondary school (Gymnasium) is determined by a variety of background characteristics, some of which are unobservable to us. Therefore, controlling for the attendance of upper secondary school will help us capture some further unobserved characteristics of the adolescent.

The propensity to give up music and secondary school type can only be measured after the start of the treatment. Previous music training thus possibly has an influence on them. Therefore, we do not include these variables in the selection model for the propensity score, but add them as control variables once we estimate outcome differences with between treatment and matched control group. This approach is similar to mediation analysis.[20]

Table 5 compares our main results with alternative specifications using mediation analysis. The results of our baseline specification (column 1 of Table 4) are printed in column (1) for comparison. As shown in column (2), these results are robust to including the probability to give up music and secondary school type as control variables. If we control for these variables, the effects on cognitive skills and ambitions decrease slightly, while all other results remain

[18] Still being engaged in music at age 17 is the precondition to be observed as a music participant in our sample.

[19] These 281 individuals answered the SOEP Youth Questionnaire in 2011 or 2012. Since 2006, the SOEP Household Questionnaire biannually asks parents about their child's leisure activities. Therefore, we have a random subsample of individuals with complete histories of musical activity since age 12.

[20] Mediation analysis is usually used to differentiate between mechanisms through which the treatment affects the outcome (Imai et al., 2010; Heckman and Pinto, 2013). To identify causal mediation effects, the intermediate variable must satisfy the sequential ignorability assumption, according to which the mediator is independent of both treatment and outcome. Our aim here is to exclude, rather than identify the effect which runs through the channel of the intermediate variable. As we are solely interested in the effect which does *not* go through the mediator, we do not need to assume sequential ignorability.

unchanged.[21]

Are the results due to reverse causality or simultaneity? A possible explanation for the positive association between music and cognitive as well as non-cognitive skills could be reverse causality or simultaneity. For example, musical activities do not increase ambition, but the more ambitious children tend to learn a musical instrument. Similarly, reverse causality could explain the positive correlation between music lessons and other outcomes such as openness, agreeableness, or even cognitive skills and school grades. Ideally, we would exclude the possibility of reverse causality by controlling for the value of the outcome before the start of the treatment. Unfortunately, due to the design of our data, we can only measure the outcome variables once, at the age of 17.

Again, mediation analysis allows us to examine the robustness of our findings to successively including outcomes as control variables. For each combination of outcomes p and q, we estimate the following model:

$$Y_i^p = \alpha + \beta \cdot Music_i + \gamma Y_i^q + \varepsilon \qquad \text{for all } p, q \text{ with } p \neq q \tag{2}$$

where control observations (with $Music_i = 0$) are weighted according to the weights obtained by propensity score matching. In other words, we examine whether the outcome difference in outcome Y^p between adolescents with and without music training, as estimated in the baseline model presented in Table 4, changes once we control for outcome Y^q. Conceptually, we insert outcome Y^q, measured like all other outcomes at the age of 17, as a proxy for the value of Y^q at a younger age. As an example, we estimate the difference in cognitive skills at age 17 between adolescents with and without music training during their childhood, controlling for conscientiousness, also measured at age 17. Of course, all other control variables used in the baseline estimation are still accounted for by applying propensity score matching. Moreover, we include the predicted propensity to give up music as well as secondary school type as further intermediate variables in each of these estimations.

Columns (3) to (5) of Table 5 provide the results for some of these mediation tests. As stated above, column (1) provides the main results from Table 4 for comparison. The other four columns show the same estimation including the variables mentioned in the table header as intermediate variables. Outcome differences between adolescents who learned a musical instrument and those who did not are very robust to including other outcomes as control variables. Even if this test is not able to entirely exclude the risk of reverse causality, we conclude that the latter is highly unlikely to entirely explain our results. Estimations including the other outcomes as intermediate variables point in the same direction and can be provided by the authors on request.

[21] As an additional test, we can show that our results are robust to a sensitivity analysis using Rosenbaum bounds (DiPrete and Gangl, 2004). Especially the effects on cognitive skills, openness, and educational plans are robust to a strongly influential unobserved confounder. Results can be provided by the authors on request.

Table 5 – *Outcome differences between adolescents with and without music training controlling for additional covariates*

	Main results	**Regression-adjustment through intermediate variables**				*Sample*
Effect of music training	(1)	(2)	(3)	(4)	(5)	*size*
Additional controls						
Probability to give up music before 17		X	X	X	X	
Attends upper secondary school		X	X	X	X	
Average cognitive skills			X			
Conscientiousness				X		
Openness					X	
Cognitive skills						
Average cognitive skills	0.24*** (0.08)	0.20** (0.08)		0.22** (0.09)	0.20** (0.10)	1,772
Analogies	0.28*** (0.09)	0.23*** (0.09)	0.08 (0.07)	0.25** (0.10)	0.23** (0.10)	1,772
Figures	0.19** (0.09)	0.20** (0.09)	0.05 (0.06)	0.24** (0.10)	0.22** (0.10)	1,772
Maths operators	0.11 (0.09)	0.06 (0.09)	-0.10^{+} (0.05)	0.07 (0.10)	0.06 (0.10)	1,772
School achievement[1]						
Average school grade	-0.17*** (0.06)	-0.15** (0.06)	-0.17^{+} (0.09)	-0.13 (0.09)	-0.18** (0.09)	3,364
German grade	-0.16** (0.06)	-0.15** (0.06)	-0.18^{+} (0.09)	-0.15^{+} (0.09)	-0.15^{+} (0.09)	3,364
Foreign language grade	-0.14** (0.06)	-0.10^{+} (0.06)	-0.13 (0.09)	-0.08 (0.09)	-0.11 (0.09)	3,364
Mathematics grade	-0.09 (0.07)	-0.09 (0.07)	-0.09 (0.10)	-0.08 (0.10)	-0.16 (0.10)	3,364
Personality						
Conscientiousness	0.28*** (0.09)	0.28*** (0.09)	0.32*** (0.11)		0.27*** (0.09)	1,753
Openness	0.33*** (0.09)	0.31*** (0.09)	0.32*** (0.11)	0.30*** (0.09)		1,753
Agreeableness	0.18^{+} (0.09)	0.19** (0.09)	0.11 (0.11)	0.13 (0.09)	0.17^{+} (0.09)	1,753
Perceived control	0.07 (0.06)	0.07 (0.06)	0.13 (0.09)	0.09 (0.08)	0.12 (0.09)	3,364
Time use						
Watch TV daily	-0.13*** (0.03)	-0.12*** (0.03)	-0.09^{+} (0.05)	-0.12** (0.05)	-0.11** (0.05)	3,364
Read books daily	0.08** (0.03)	0.06^{+} (0.03)	0.08 (0.05)	0.08^{+} (0.04)	0.06 (0.05)	3,364
Ambition						
Aim Abitur	0.15*** (0.03)	0.09*** (0.02)	0.09** (0.04)	0.09** (0.04)	0.07** (0.04)	3,364
Aim university	0.18*** (0.03)	0.12*** (0.03)	0.14*** (0.04)	0.12*** (0.04)	0.11** (0.04)	3,364
Job success likely	0.07 (0.06)	0.07 (0.06)	0.12 (0.09)	0.03 (0.09)	0.06 (0.09)	3,364
Desired profession likely	0.07 (0.06)	0.09 (0.06)	0.14 (0.09)	0.09 (0.08)	0.12 (0.08)	3,364

[1] Note that in Germany, better performance is rewarded with a lower school grade.

Source: SOEPv29 (2001-2012), own calculations. Column (1) shows the baseline results (Column (1) of Table 4. Columns (2) to (5) show the same estimations, including additional control variables (intermediate variables) as indicated in the upper part of the table. Propensity score matching (radius matching with caliper 0.01) is used to account for standard control variables from baseline specification, OLS to estimate outcome differences between treatment and matched control group with additional control variables. The sample size is smaller for cognitive skills and some personality measures, as these have only been assessed since 2006. Standard errors in parentheses are clustered at the household level and estimated by bootstrap (1999 replications). Significance levels: $^{+}$ $p<0.1$ * $p<0.05$ *** $p<0.01$

Existence of partly treated individuals in the control group. Some individuals in our control group have received music training for a number of years. They are in the control group either because they started to learn a musical instrument later than age 8 or because they gave up before age 17. Irrespective of the conditional independence assumption, the existence of partly treated individuals in the control group influences the direction in which our estimates differ from the true effect of learning a musical instrument. If adolescents benefit to some extent even from short-term musical experience, we do not have to worry. In this case, our estimates are a lower bound of the true effect, given that some members of the control group also benefit from the treatment. A more worrisome conclusion follows if short-term musical experience harms skill development. If the true effect of music training is positive when carried out at least from age 8 to 17, but negative for shorter periods of music training, we overestimate the true effect even if the conditional independence assumption is valid. In this case, our estimated average effect would add the positive effect in the treatment group to the negative effect among the partly treated. In order to obtain the true effect, we would have to subtract these effects from each other.

We can provide some empirical evidence according to which partly treated individuals weakly benefit from music training. We are able to identify individuals who started music practice later than age 8, because they answer the questions on musical practice at age 17. Column (1) of Table A.11 in the appendix shows the effects of music training for these individuals. Here we consider those adolescents as treated, who play music at age 17, but do not fulfill the requirements of the treatment definition in our main specification.[22] Moreover, we exclude the treated individuals of our main specification from the sample.

The effects of playing a musical instrument later than the age of 8 are weaker, but still positive, compared with children who start to learn a musical instrument earlier. While the effects on cognitive skills, openness and ambition are still relatively strong, those on school marks and conscientiousness are no longer significant.

Unfortunately, it is more difficult to estimate the effect of music on those who gave up music training before age 17, because the SOEP Youth Questionnaire does not ask them about past musical activities. Around 60 percent of all musically active children give up in their early teenage years. The three most important reasons are a lack of motivation, critical life events, and dissatisfaction with the teacher (Switlick and Bullerjahn, 1999). Hence, ending music training is possibly related to weaker school performance. We can test this hypothesis using the SOEP household questionnaire, which has been asking parents about their child's leisure time activities on a biannual basis since 2006. As described above, this allows us to construct a random subsample[23] of 281 individuals, for whom we observe the complete history of musical activities since age 12. We can therefore compare outcome differences between those who never played a musical instrument after age 12 to those who played a musical instrument at age 12

[22] To be precise, to be considered as treated in column (1) of Table A.11, the individual hast to: 1) play a musical instrument at age 17, and 2) have started to play music later than age 8 (with or without music lessons) or 3) have started to play at age 8 or earlier, but never taken music lessons outside of school.

[23] The subsample is random because it consists of all observations which were interviewed in 2011 and 2012 and have been in the SOEP since 2006. These facts are exogenous to all individual or family characteristics.

and gave up before age 17. Similar to all other estimations, we apply propensity score matching to account for observable family background characteristics.[24]

The effects of music for this small subsample are presented in column (2) of Table A.11 in the appendix. Due to the small sample size, none of the outcome differences are significant. Still we see that for most outcomes the direction of the effect is still the same, whereas its magnitude is greatly reduced. When it comes to cognitive skills, individuals who gave up music training seem to score slightly lower than those who were never involved with music. For the causal interpretation of our main results, this means that we might overestimate the true effect of music on cognitive skills, because some of the partly treated individuals might actually suffer from the stresses of demanding musical practice.

We conclude that the existence of partly treated individuals in the control group is unlikely to lead us to overestimate the treatment effect. If the conditional independence assumption is valid, we might even underestimate the true effect of learning a musical instrument on some outcomes.

7. Conclusion

The present study shows that even after controlling for a large number of parental background differences, learning a musical instrument is associated with better cognitive skills and school grades as well as higher conscientiousness, openness, and ambition. Adolescents who have learned a musical instrument at least between age 8 and 17 score more than one fourth of a standard deviation above other children in a cognitive skills test. This advantage is driven by verbal rather than mathematical skills. Adolescents who are enrolled in music lessons are more conscientious and open (more than one fourth of a standard deviation). They are more than 10 percent less likely to watch TV daily and about 15 percent more likely to aim at completing upper secondary school and attending university. Moreover, adolescents of low or medium socio-economic status with music training are more optimistic about their future chances of success. Other than that, results do not differ by socio-economic origin. Sports and dance, as alternative leisure activities, also positively benefit skill development. In particular, sporty adolescents are similarly ambitious with respect to the completion of secondary school or university attendance than those with music training. Moreover, adolescents who play theater or dance, are more optimistic about their future and have an increased perception of control. Still, with respect to cognitive skills, school marks and conscientiousness, the effects of music are much stronger than those of sports, theater and dance.

Our analysis encounters three risks which could question a causal interpretation of our results. We address each of them with a set of robustness tests. First, our results might be driven by unobserved heterogeneity. We argue that we are able to take into account the non-random decision to engage in music training at age 8 using a large number of parental background information, which we control for. However, unobserved individual characteristics could determine the decision to keep on taking music lessons until age 17 rather than giving up earlier.

[24] However, due to the small sample size, we had to omit some covariates in order to avoid collinearity. Moreover, the sample size is too small to estimate standard errors by bootstrap. We present standard errors which do not take into account that the propensity score was estimated.

Therefore, we additionally control for the predicted probability to give up music before age 17 as well as the adolescent's secondary school type. Second, we examine the sensitivity of our results to reverse causality by performing mediation analysis in which we estimate the correlation between music practice and outcome p, while subsequently controlling for all outcomes q other than p. We observe that the pattern of correlation between music and cognitive as well as non-cognitive skills remains stable when we include any of the other outcome variables as controls. Reverse causality is therefore unlikely to explain our results. Third, we consider individuals as treated if they learned a musical instrument at least from age 8 to 17. Thus, some individuals in the control group were partly treated as well, because they either started to take music lessons after age 8 or gave up before age 17. Our results potentially overestimate the true effect of music training if music harms skill development among these partly treated individuals. A test with a small subsample of our data for which we are able to reconstruct the individual history of music training reveals that cognitive skills are probably the only outcome for which such a risk of overestimation is present. To conclude, even though we cannot entirely exclude the possibility that unobserved heterogeneity drives our results, we approach causality better than any previous observational study on the effects of music training.

The strong effect of music training on a variety of cognitive and non-cognitive skills indicates that music is potentially an important input in the skill production function (Cunha and Heckman, 2008; Todd and Wolpin, 2003). More research should be carried out to understand the causal influence of music practice on the development of skills. In our view, three challenges should determine the agenda of future research on this question. The most important challenge will be to separate the influence of parental and individual background from the influence of music lessons. In order to do so, it would be necessary to identify a variable that influences the decision to learn a musical instrument without influencing the development of skills. Policy interventions and other variations in the regional availability of music lessons might be as "natural experiments" a promising way to carry out causal studies on the effects of music by providing a truly exogenous selection into treatment.

A second challenge will be to answer the question of the extent to which extracurricular activities are substitutable. Theoretical considerations, previous research (Covay and Carbonaro, 2010), as well as the results of this study suggest that some types of skills might be improved through participation in extracurricular activities in general, while others are influenced particularly by music. These findings may be useful in informing policies similar to those described in the introduction that have been proposed to provide theater or sports lessons to children from disadvantaged social backgrounds. While policy makers have recognized the potential of such activities, there is still a lack of empirical research to support their implementation. Further research on the potential of different types of activities should be carried out by carefully modeling the interaction between activities that may be substitutes or complements.

Finally, further research should investigate the long-term effects of learning a musical instrument on outcomes such as labor market success or life satisfaction. It is possible that learning a musical instrument has additional positive effects extending beyond educational achievement. Mechanisms such as the signaling effect or an increased sense of determination might develop fully only at the entry into the labor market.

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Appendix A. Further tables and figures

Table A.6 – *List of outcome variables*

Variable	Items	Measurement and units	
		In raw data	*In this study*
Cognitive skills			
Cognitive skills	→ Figures (find next figure in row) → Analogies (identify word pairs, e.g. meadow-grass vs. forest-? [trees]) → Maths (insert maths operators)	Test score: 0-20 points	std. deviation (normalized)
Educational achievement			
School grades	→ German grade → First foreign language grade → Math grade	Self-reported: 1 (very good) - 6 (fail)	std. deviation (normalized by school type)
Personality			
Conscientiousness	→ Are you rigorous? → Are you lazy? (–) → Are you efficient?	Self-assessment: 1 (does not apply) - 7 (applies perfectly)	std. deviation (normalized)
Openness	→ Are you original? → Do you value artistic experiences? → Do you have phantasy? → Are you eager for knowledge	Self-assessment: 1 (does not apply) - 7 (applies perfectly)	std. deviation (normalized)
Agreeableness	→ Are you sometimes rough with others? (–) → Are you able to forgive? → Are you considerate/friendly?	Self-assessment: 1 (does not apply) - 7 (applies perfectly)	std. deviation (normalized)
Perceived control	→ How my life goes, depends on myself → Compared to others, haven't achieved what I deserved (–) → What one achieves is mainly a question of luck/fate (–) → I often have the experience that others make decisions regarding my life (–) → When I encounter difficulties I have doubts about my abilities (–) → Opportunities in life determined by social conditions (–) → Little control over the things that happen in my life (–)	Self-assessment: 1 (disagree completely) - 7 (agree completely)	std. deviation (normalized)
Time use			
TV	→ Watch TV daily	binary	percent
Reading	→ Read books daily	binary	percent
Ambition			
School degree	→ Aim upper secondary school degree (Abitur)	binary	percent
University	→ Are you aiming to enroll at a university?	binary	percent
Desired profession	→ How likely to find a job in your field?	in percent	std. deviation
Job success likely	→ How likely to be succesful and get ahead?	in percent	std. deviation

Table A.7 – *List of control variables for main specification and mediation analysis*

Variable	Units	Measured when?
Parents' socio-economic background		
Mother[1] has no degree	binary	age 5 or entry[2]
Mother[1] has completed only 9 school years	binary	age 5 or entry[2]
Mother[1] has vocational degree	binary	age 5 or entry[2]
Mother[1] has university degree	binary	age 5 or entry[2]
Monthly household log net income (simple, squared)[4]	continuous	age 5 or entry[2]
Mother[1] has migration background	binary	age 5 or entry[2]
Mother's age at birth[4]	in years	age 5 or entry[2]
Number of siblings	number	age 5 or entry[2]
Child is the firstborn	binary	age 5 or entry[2]
Rooms per person at home	number	age 5 or entry[2]
Parents' personality		
Conscientiousness (mother[1,4,5])	normalized	2005 or 2009[3]
Extraversion (mother[1,4,5])	normalized	2005 or 2009[3]
Neuroticism (mother[1,4,5])	normalized	2005 or 2009[3]
Agreeableness (mother[1,4,5])	normalized	2005 or 2009[3]
Openness (mother[1,4,5])	normalized	2005 or 2009[3]
Parental involvement in the child's school success		
Parents care about school achievement	binary	retrospectively at 17
Parents do not support learning	binary	retrospectively at 17
Conflict with parents due to school results	binary	retrospectively at 17
Parents attend parent-teacher meetings	binary	retrospectively at 17
Parents attend teacher's consultation hours	binary	retrospectively at 17
Parents actively contact school teachers	binary	retrospectively at 17
Parents engage as parent representatives	binary	retrospectively at 17
Parents do not engage with child's school	binary	retrospectively at 17
Parents' taste for the arts		
Mother[1,4] monthly attend cultural events	binary	age 5 or entry
Mother[1,4] never attend cultural events	binary	age 5 or entry
Mother[1,4] are monthly artistically active	binary	age 5 or entry
Mother[1,4] are never artistically active	binary	age 5 or entry
Appreciation for the arts (mother[1,4])	normalized	age 5 or entry
Further control variables included in main specification		
Gender	binary	time constant
Birth year (10 dummies)	binary	time constant
Rural area	binary	time constant
Federal state (15 dummies)	binary	time constant
SOEP sub-sample (7 dummies)	binary	time constant
Further control variables included in mediation analysis (Table 5)		
Probability to give up music before age 17	percent	predicted
Adolescent attends upper secondary school (Gymnasium)	binary	time constant

[1] Mother's value if available, otherwise the father's value is used.
[2] If the household was not in the SOEP when the child was aged 5, these variables were measured in the year the household entered the SOEP. About 60 percent of the sample entered the SOEP later than age 5. On average, individuals enter the sample at age 8.2.
[3] The earliest year with non-missing observation.
[4] Set to mean value if missing and missing indicator included.
[5] For items and measurement, please refer to Table A.6.

Figure A.1 – *Common support graph (for main specification with main sample)*

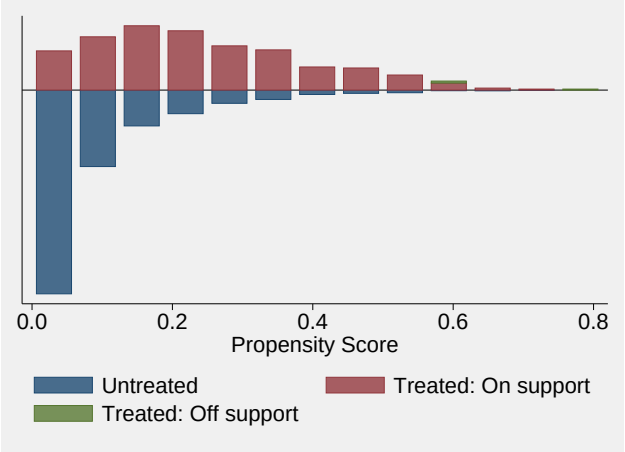

Table A.9 – *Common support*

	Main sample		**Cog. skills sample**		**Big 5 sample**	
	Control	Treated	Control	Treated	Control	Treated
Off support	0	3	0	7	0	7
On support	2,997	369	1,568	205	1,531	223

Source: SOEP v29 (2001-2012 pooled), own calculations. The table shows the common support for the three samples used in our main specification. The sample sizes for cognitive skills and Big 5 personality traits is smaller because these outcomes have been measured only since 2006. For each treated individual, radius matching with a caliper of 0.01 is performed to find appropriate matches in the control group.

Table A.8 – *Estimation of the propensity score for all three subsamples*

	Have music lessons at least between age 8 and 17					
	Main sample		Cog. skills sample		Big 5 sample	
	(1)		(2)		(3)	
Parents' education and household characteristics						
University degree	0.48***	(0.09)	0.53***	(0.12)	0.38***	(0.11)
Parent with lower secondary school degree	-0.11	(0.08)	0.10	(0.11)	-0.08	(0.10)
Mother (father) has no degree	-0.09	(0.15)	-0.17	(0.21)	-0.39^{+}	(0.21)
Vocational degree	0.09	(0.10)	0.18	(0.13)	0.01	(0.13)
Monthly HH net income (log)	-0.27	(1.10)	-2.79^{+}	(1.53)	-3.88**	(1.63)
Monthly net log HH income (square)	0.02	(0.07)	0.19^{+}	(0.10)	0.25**	(0.10)
Migration background	0.03	(0.12)	0.10	(0.18)	0.14	(0.16)
Girl	0.43***	(0.07)	0.49***	(0.09)	0.38***	(0.08)
Oldest child in family	-0.01	(0.07)	-0.03	(0.10)	0.02	(0.10)
Number of siblings	0.01	(0.03)	0.01	(0.04)	0.00	(0.04)
Rooms per person	0.14^{+}	(0.08)	0.26**	(0.12)	0.24**	(0.11)
Mother's age at birth	0.01	(0.01)	-0.01	(0.01)	0.01	(0.01)
Rural area	-0.08	(0.10)	-0.24^{+}	(0.14)	-0.14	(0.14)
Parents care strongly about school achievement	0.04	(0.08)	0.08	(0.10)	0.02	(0.10)
Parents' involvement with school						
Parents don't support learning	0.01	(0.08)	0.03	(0.11)	0.06	(0.10)
Conflict with parents due to school results	-0.03	(0.07)	-0.03	(0.09)	-0.05	(0.09)
Parents go to parent-teacher meeting	0.09	(0.10)	0.15	(0.13)	0.07	(0.12)
Parents go to teacher's consultation hours	-0.06	(0.07)	-0.14	(0.10)	-0.10	(0.09)
Parents actively contact school teachers	0.03	(0.08)	0.25**	(0.10)	0.11	(0.10)
Parents engage as parent representatives	0.34***	(0.08)	0.31***	(0.11)	0.24**	(0.11)
Parents don't engage with the child's school	-0.08	(0.16)	-0.04	(0.21)	-0.09	(0.20)
Conscientiousnes	-0.01	(0.32)	-0.01	(0.42)	0.21	(0.42)
Parents' personality						
Extraversion	-0.20	(0.24)	-0.74**	(0.31)	-0.56^{+}	(0.30)
Agreeableness	-0.31	(0.28)	-0.21	(0.36)	-0.27	(0.37)
Openness	-0.55	(0.36)	-0.03	(0.50)	-0.27	(0.47)
Neuroticism	0.17	(0.20)	0.11	(0.25)	0.10	(0.25)
No cultural events	-0.31***	(0.09)	-0.27**	(0.13)	-0.30**	(0.12)
Parents' taste for the arts						
Monthly cultural events	0.30***	(0.09)	0.31**	(0.12)	0.23^{+}	(0.13)
No artistic activities	-0.21**	(0.09)	-0.17	(0.12)	-0.16	(0.11)
Monthly artistic activities	-0.02	(0.09)	0.22**	(0.11)	0.11	(0.11)
Appreciation for art (parents)	0.83***	(0.24)	0.43	(0.32)	0.70**	(0.31)
Constant	-1.55	(4.37)	8.37	(5.96)	12.75**	(6.38)
Sample, birth and region fixed effects	Yes		Yes		Yes	
Number of observations	3,369		1,780		1,761	
Pseudo-R-Square	0.20		0.22		0.18	

Source: SOEP v29 (2001-2012 pooled), own calculations. Probit model estimating the probability to be treated. Treatment definition: Have music lessons at least between age 8 and 17. The sample for cognitive skills and Big 5 personality traits is smaller because these variables were measured only since 2006. Standard errors in parentheses. Significance levels: $^{+}$ $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

Table A.10 – *Balancing of covariates after propensity score matching (Main sample)*

	Before matching		After matching	
	Difference	t-value	Difference	t-value
Parents' education and household characteristics				
Monthly HH net income	1,028.40***	11.21	-17.62	-0.11
University degree	0.35***	13.87	-0.00	-0.04
Parent with lower secondary school degree	-0.20***	-7.31	0.00	0.14
Mother (father) has no degree	-0.11***	-5.60	0.01	0.53
Vocational degree	-0.06**	-2.28	-0.00	-0.02
Migration background	-0.08***	-3.96	-0.00	-0.18
Girl	0.16***	5.95	0.00	0.05
Oldest child in family	-0.05^{+}	-1.67	0.02	0.41
Number of siblings	0.03	0.53	0.03	0.34
Rooms per person	0.15***	6.44	0.00	0.16
Rural area	-0.06**	-2.54	-0.01	-0.24
Parents' taste for the arts				
No cultural events	-0.26***	-9.81	0.00	0.19
Monthly cultural events	0.17***	10.05	0.02	0.47
No artistic activities	-0.26***	-9.46	-0.00	-0.05
Monthly artistic activities	0.18***	8.06	0.02	0.65
Appreciation for art (parents)	0.09***	6.73	-0.00	-0.13
Parents' involvement with school				
Parents care strongly about school achievement	0.01	0.45	-0.01	-0.18
Parents don't support learning	-0.04	-1.55	0.00	0.12
Conflict with parents due to school results	-0.07***	-2.63	-0.01	-0.33
Parents go to parent-teacher meeting	0.08***	3.47	0.00	0.04
Parents go to teacher's consultation hours	-0.00	-0.07	-0.01	-0.15
Parents actively contact school teachers	0.04	1.54	0.01	0.39
Parents engage as parent representatives	0.17***	8.36	0.01	0.34
Parents don't engage with the child's school	-0.04**	-2.48	-0.00	-0.25
Parents' personality				
Conscientiousnes	-0.01**	-2.23	-0.00	-0.04
Extraversion	-0.00	-0.09	-0.00	-0.44
Agreeableness	-0.01	-1.47	-0.01	-0.70
Openness	0.03***	3.89	-0.00	-0.18
Neuroticism	-0.01	-1.31	0.00	0.19

Source: SOEP v29 (2001-2012 pooled), own calculations. Differences between adolescents with and without music training before and after matching for the main sample (used for all outcomes except cognitive skills and Big 5 personality traits). Balancing tables for these other two samples can be provided by the authors on request. Significance levels: $^{+}$ $p < 0.1$ ∗∗ $p < 0.05$ ∗∗∗ $p < 0.01$

Table A.11 – *Outcome differences between adolescents with and without music training (partly treated individuals)*

	Music lessons after age 8 or music practice without lessons		**Adolescents who gave up music before age 17**	
Effect of music training	(1)		(2)	
Size of subsample	2,997		238	
Treated	478		50	
Control	2,519		188	
Off support (treated)	6		5	
Cognitive skills				
Average cognitive skills	0.11^{+}	(0.07)	-0.10	(0.23)
Analogies	0.15**	(0.07)	-0.11	(0.21)
Figures	0.17**	(0.07)	0.06	(0.24)
Maths operators	-0.01	(0.07)	-0.15	(0.22)
School achievement[1]				
Average school grade	-0.06	(0.05)	0.08	(0.21)
German grade	-0.08	(0.05)	-0.08	(0.20)
Foreign language grade	-0.02	(0.06)	0.27	(0.21)
Mathematics grade	-0.05	(0.06)	-0.01	(0.21)
Personality				
Conscientiousness	-0.05	(0.07)	0.23	(0.19)
Openness	0.38***	(0.08)	0.16	(0.21)
Agreeableness	0.17**	(0.07)	0.14	(0.18)
Perceived control	0.03	(0.06)	0.27	(0.20)
Time use				
Watch TV daily	-0.03	(0.02)	0.03	(0.10)
Read books daily	0.10***	(0.02)	-0.08	(0.08)
Ambition				
Aim Abitur	0.12***	(0.03)	-0.01	(0.11)
Aim university	0.13***	(0.03)	-0.00	(0.10)
Job success likely	-0.05	(0.05)	0.01	(0.18)
Desired profession likely	0.00	(0.05)	0.11	(0.17)

[1] Note that in Germany, better performance is rewarded with a lower school grade.

Source: SOEPv29 (2001-2012), own calculations. Column (1) shows the effects of music training for those who started music lessons later than age 8 (and kept taking them until age 17) or who played music without taking lessons. Column (2) shows the effects of music training for those who played music at age 12 but gave up before age 17. Both sets of estimations were conducted with a specific subsample of the main sample (please refer to the text for more information). Propensity score matching is used to account for standard control variables from baseline specification (radius matching with caliper 0.01 for column (1). Due to the small sample size, we use a caliper of 0.1 in column (2)). In column (2), the set of control variables was slightly reduced to exclude collinearity. In column (1), the sample size is smaller for cognitive skills and some personality measures, as these have only been assessed since 2006. In column (1), standard errors in parentheses are clustered at the household level and estimated by bootstrap (1999 replications), in column (2), due to the small sample size, standard errors do not take into account that the propensity score was estimated. Significance levels: $^{+}$ $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$