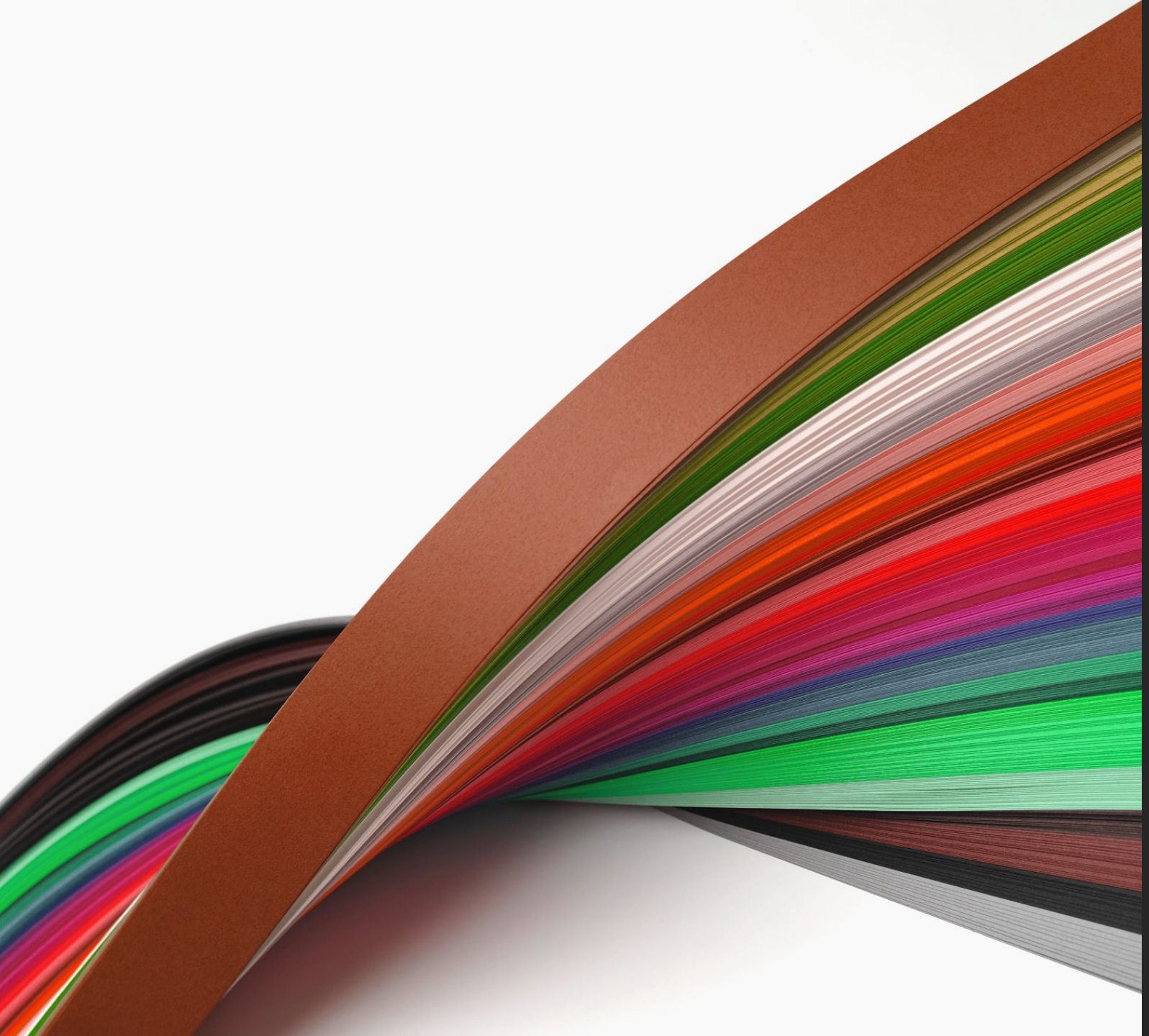


Working Memory, Intelligence, Music Perception, and Musical Training: Development during Adolescence

DANIEL MÜLLENSIEFEN, GOLDSMITHS, UNIVERSITY OF LONDON & UNIVERSITY OF MUSIC, DRAMA & MEDIA, HANNOVER

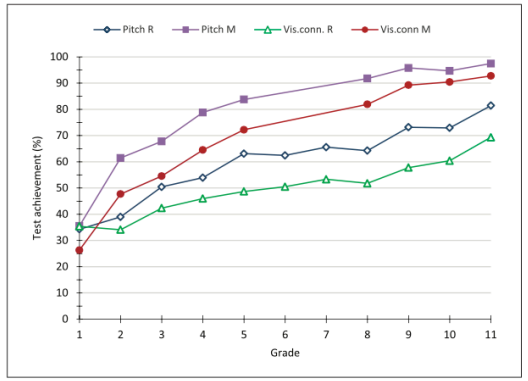
The Question

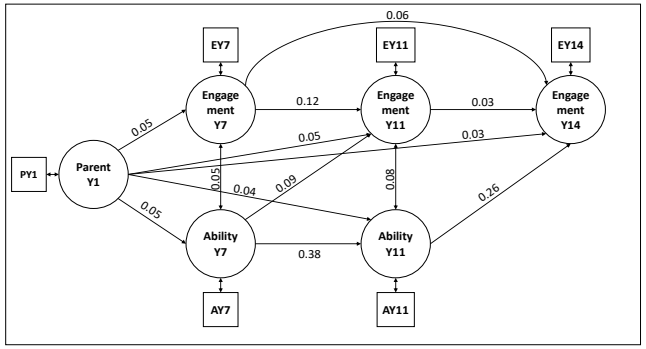
What role do musical abilities and activities play in human development across the teenage years?

LongGold Study

Longitudinal assessment of musical abilities, cognitive skills, academic performance, personality, and psycho-social variables across secondary school years

Why?



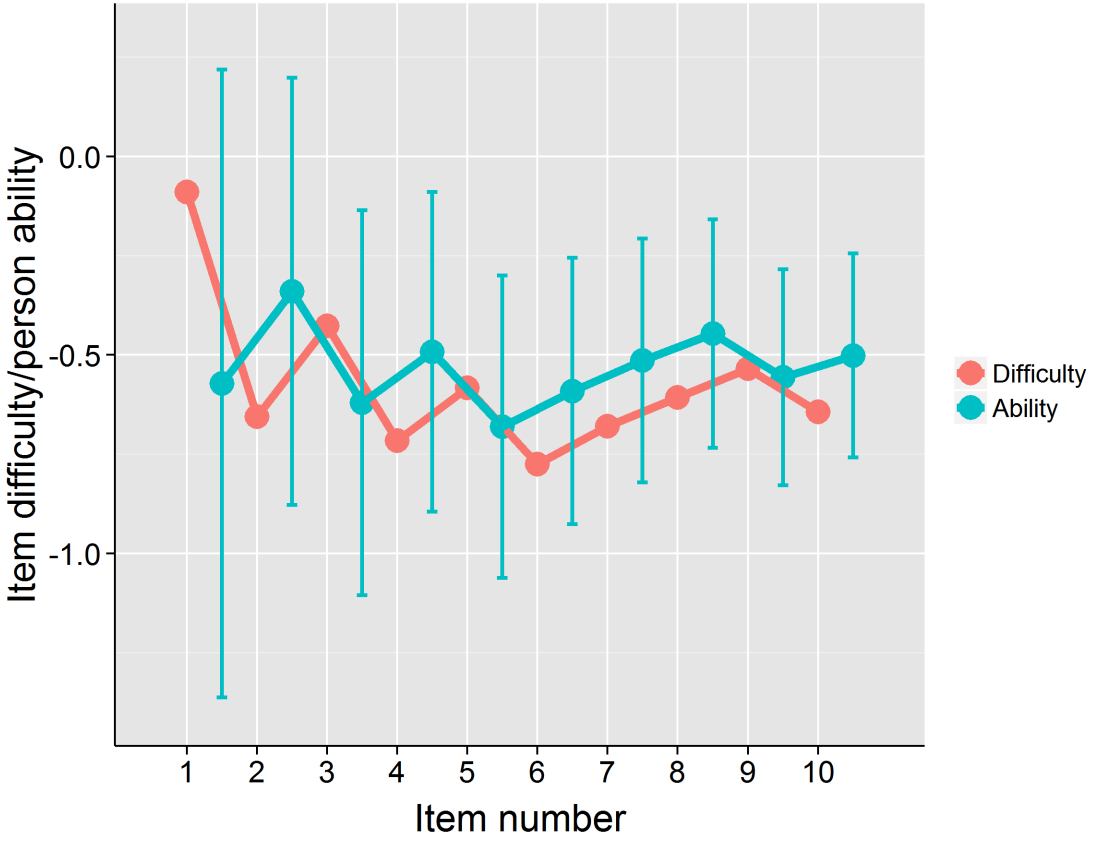


- Description of musical development due to maturation, training, and individual differences factors
- Causal factors driving musical development
- Who will take up music seriously? (Who will give it up again?)
- Transfer effects from
  - Music => Other Domains
  - Other Domains => Music
- Is music special when compared to sports and theatre activities?

How?

- Annual assessment over 5 to 7 years
- ~4000 students from secondary schools in UK and Germany
- 15 tests and questionnaires in 90 mins
  - Musical abilities (melodic memory, beat perception, intonation, rhythm processing, etc.)
  - Cognitive skills (IQ, memory)
  - Personality
  - Attitudes, mental well-being, social skills
  - Musical and leisure activities
- Browser-based test interface under supervision in classrooms
- Use of efficient adaptive tests

Computerised adaptive testing (CAT)



Final ability estimate:
-0.5 ± 0.3

- Participant ability estimated after each item according to parametric model (item response theory)
- The next item is selected to match the participant's ability as closely as possible
- Tests are maximally efficient (~5 min/test)
- Test length is flexible => trade-off between test length and measurement error

Battery of adaptive music tests

Published:

Melody discrimination (Harrison, Collins, & Müllensiefen, 2017)
Beat Perception (Harrison & Müllensiefen, 2018)
Mistuning perception (Larrouy-Maestri, Harrison & Müllensiefen, 2019)
Emotion Discrimination (MacGregor & Müllensiefen, 2019)
Pitch imagery (Gelding et al., 2020)
Timbre perception and matching (Lee & Müllensiefen, 2020)

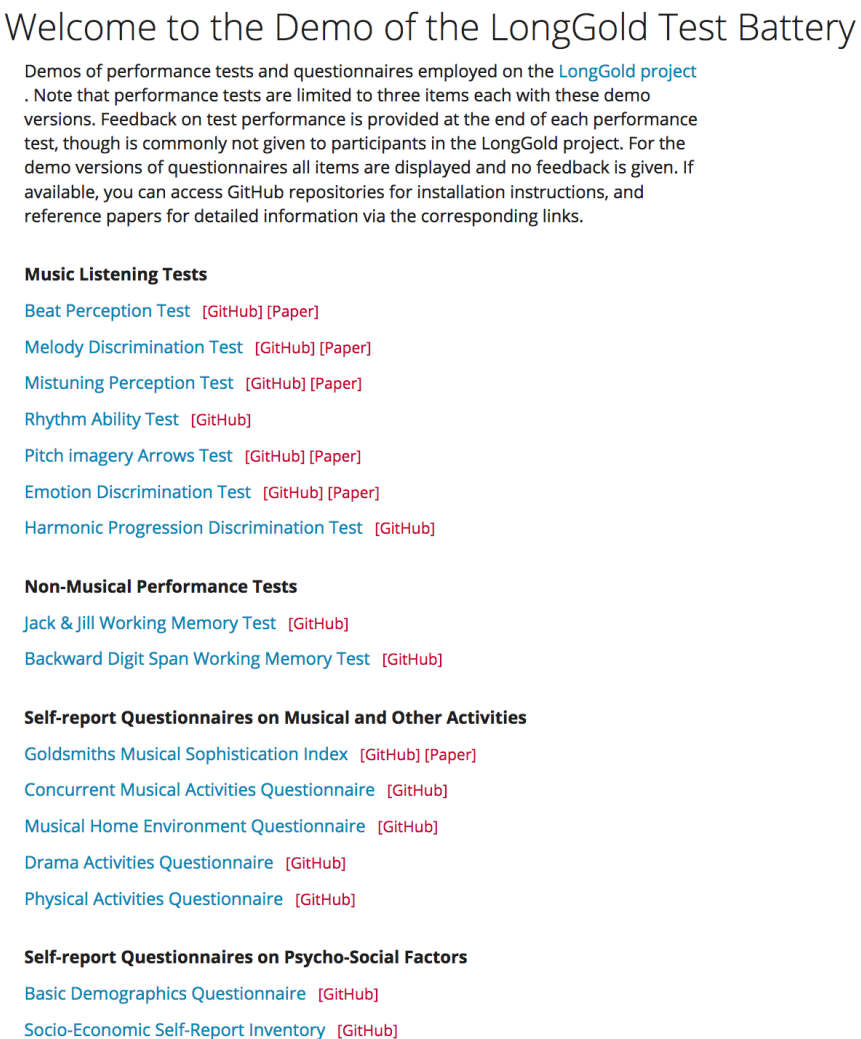
In review / write-up:

Rhythm Perception
Harmony perception
Beat Drop Test (with Patel, Cannon)

In Construction

- Musical Scene Analysis
- Statistical learning of pitch sequences
- Room acoustics
- Comparing performances
- Production *tasks:*
  - Singing
  - Beat tapping

Demos and download at: https://shiny.gold-msi.org/longgold_demo/



Welcome to the Demo of the LongGold Test Battery

Demos of performance tests and questionnaires employed on the LongGold project . Note that performance tests are limited to three items each with these demo versions. Feedback on test performance is provided at the end of each performance test, though is commonly not given to participants in the LongGold project. For the demo versions of questionnaires all items are displayed and no feedback is given. If available, you can access GitHub repositories for installation instructions, and reference papers for detailed information via the corresponding links.

Music Listening Tests

Beat Perception Test [GitHub] [Paper]

Melody Discrimination Test [GitHub] [Paper]

Mistuning Perception Test [GitHub] [Paper]

Rhythm Ability Test [GitHub]

Pitch imagery Arrows Test [GitHub] [Paper]

Emotion Discrimination Test [GitHub] [Paper]

Harmonic Progression Discrimination Test [GitHub]

Non-Musical Performance Tests

Jack & Jill Working Memory Test [GitHub]

Backward Digit Span Working Memory Test [GitHub]

Self-report Questionnaires on Musical and Other Activities

Goldsmiths Musical Sophistication Index [GitHub] [Paper]

Concurrent Musical Activities Questionnaire [GitHub]

Musical Home Environment Questionnaire [GitHub]

Drama Activities Questionnaire [GitHub]

Physical Activities Questionnaire [GitHub]

Self-report Questionnaires on Psycho-Social Factors

Basic Demographics Questionnaire [GitHub]

Socio-Economic Self-Report Inventory [GitHub]

LONGGOLD

Different from other studies?

- No music intervention
- Covering adolescent period
- Focus on musical development AND cognitive abilities, traits, attitudes

Domains of development studied in LongGold

1. Academic Development (grades)

2. Cognitive Development (IQ, working memory)

3. Musical development (listening skills and musical activity)

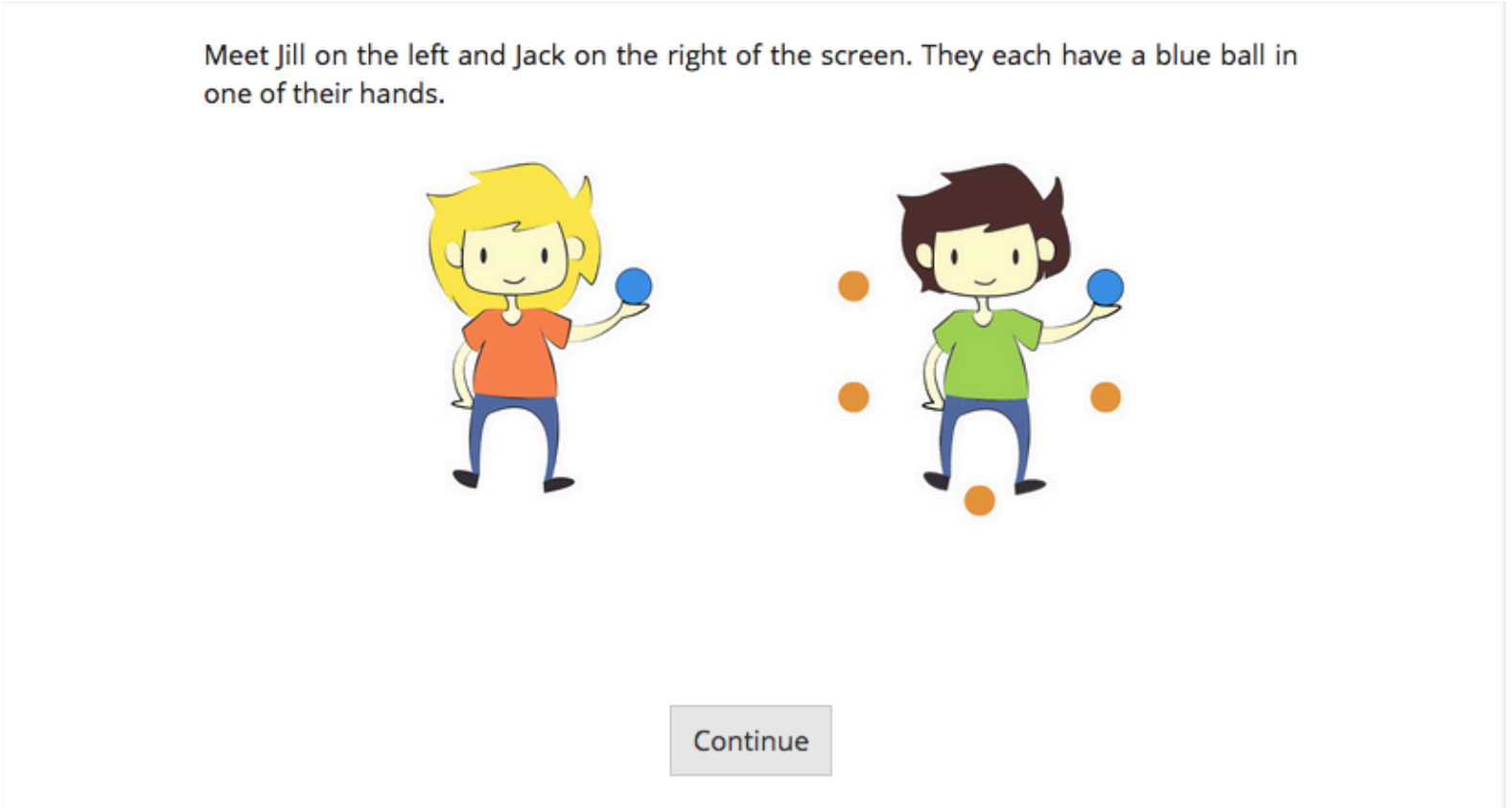
4. Psycho-social development (growth mindset, personal strengths and difficulties, school engagement, social and academic self-concepts)

5. Personality (big 5 personality traits)

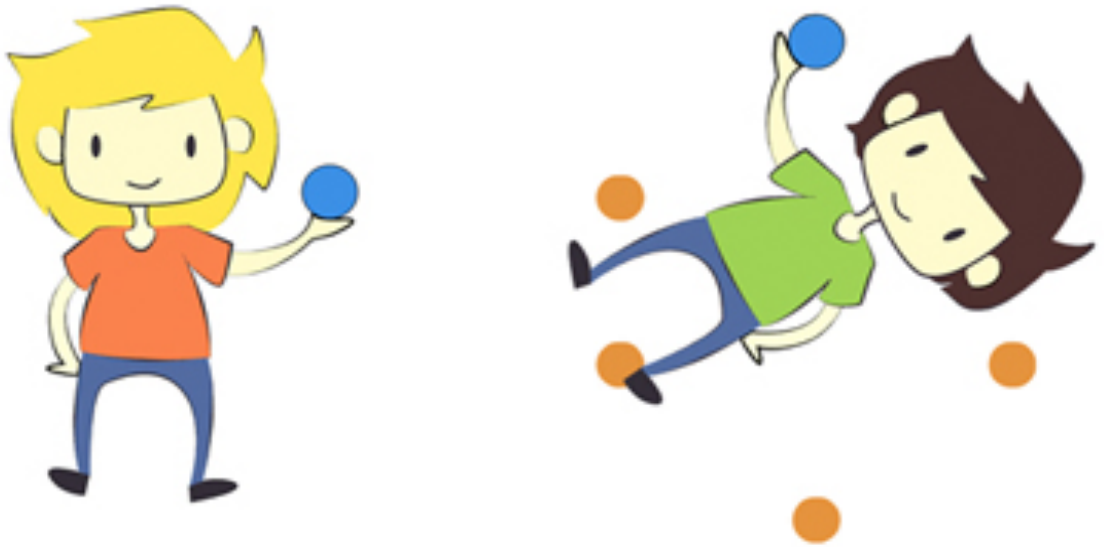
The development of working memory and the role of music

- Working memory closely related to
  - general intelligence (Ackerman et al., 2005), fluid intelligence (Cochrane et al., 2019)
  - academic achievement (Gathercole et al., 2016),
  - poor emotional control and regulation (Holmes et al., 2014)
  - Music training (Yurgil et al., 2020)
- "Brain's conductor" (Alloway & Alloway, 2013), a "cognitive primitive" (Basak & Zelinski, 2013), constrains the acquisition and deployment of most intellectual abilities (Conway et al., 2013).
- The early teenage years are an important period for the development of working memory capacity.
- What is the role of music for working memory development during this period?

Measuring working memory: The Jack & Jill task



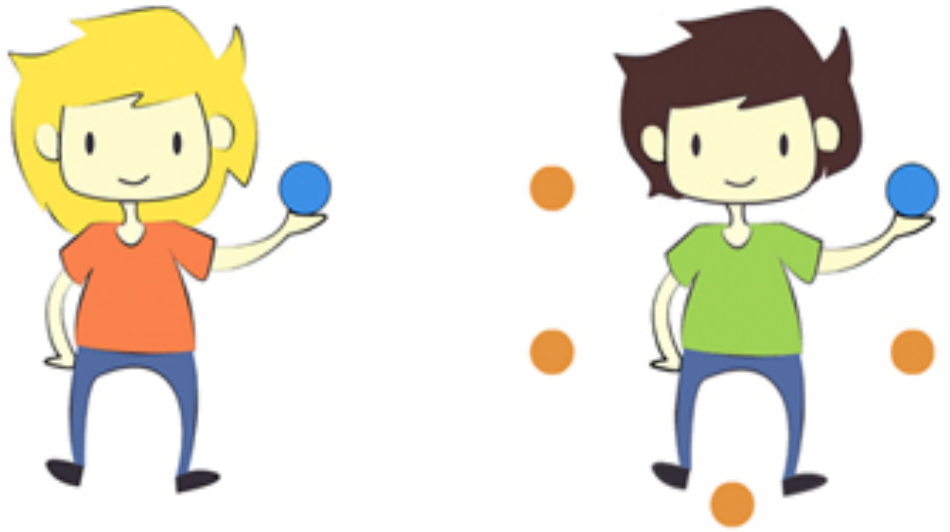
Does Jack hold the ball in the same hand as Jill?
Remember where the ball is when Jack turns.



Same | Different

1

Does Jack hold the ball in the same hand as Jill?
Remember where the ball is when Jack turns.

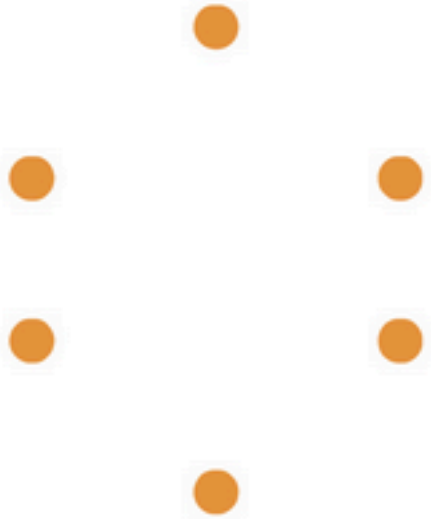


Same | Different

2

Example 1

Click the orange spots where you saw the ball move to in the same order that Jack turned.



Click the orange spots where you saw the ball move to in the same order that Jack turned.

3

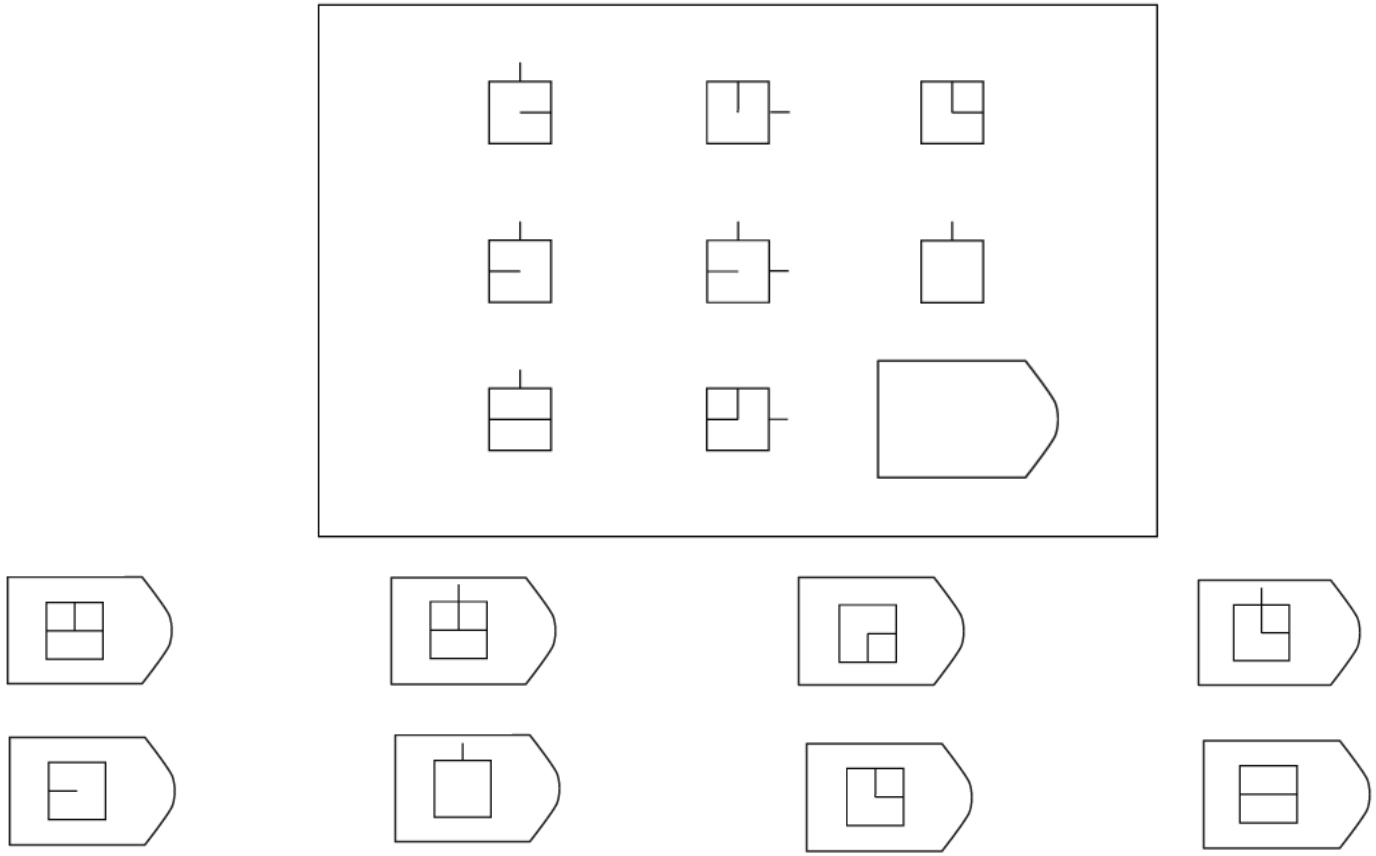
Click the orange spots where you saw the ball move to in the same order that Jack turned.

4

The Jack & Jill task

- Dual task paradigm: related to Baddeley & Hitch WM model, based on validated tasks (Shah & Miyake, 1996; Alloway et al., 2004)
- Requires storage and simultaneous processing of information
- Efficient through adaptive mechanism based on item response model (Tsigeman et al., in review)
- Takes ~ 5mins (minimum)
- Visually appealing to children

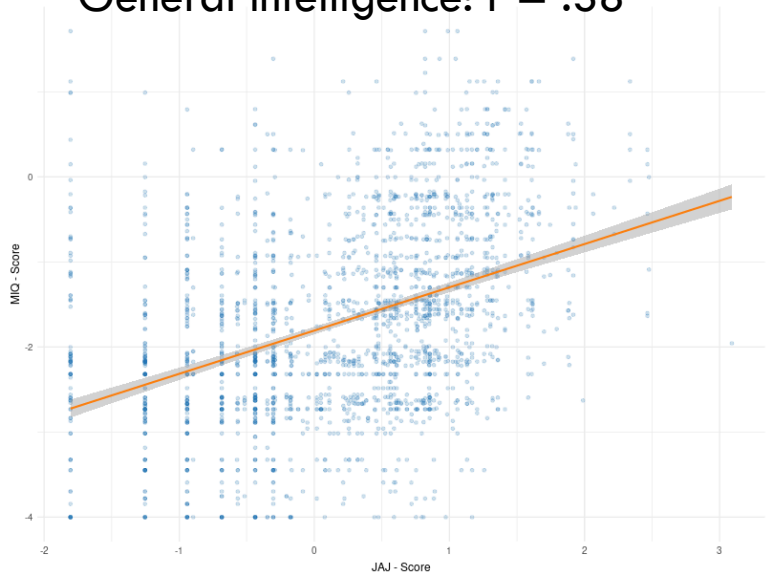
Measuring intelligence: Ravens-type matrix reasoning



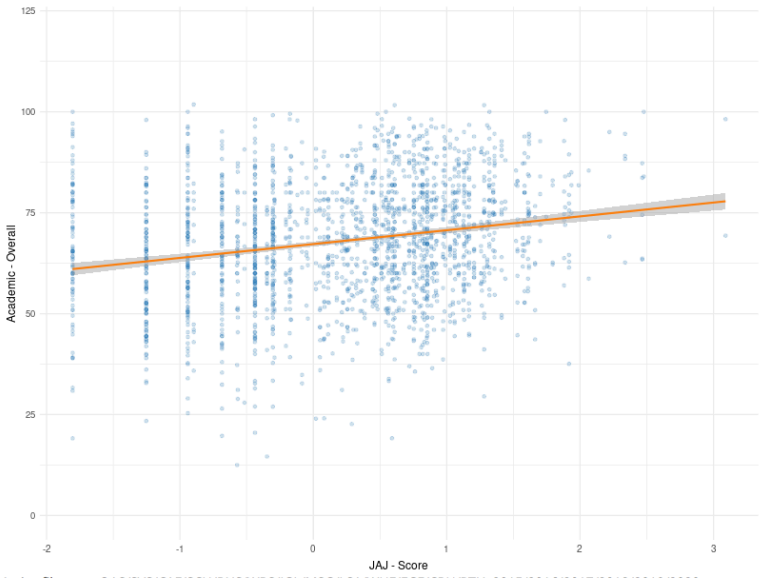
Results

WM correlates with

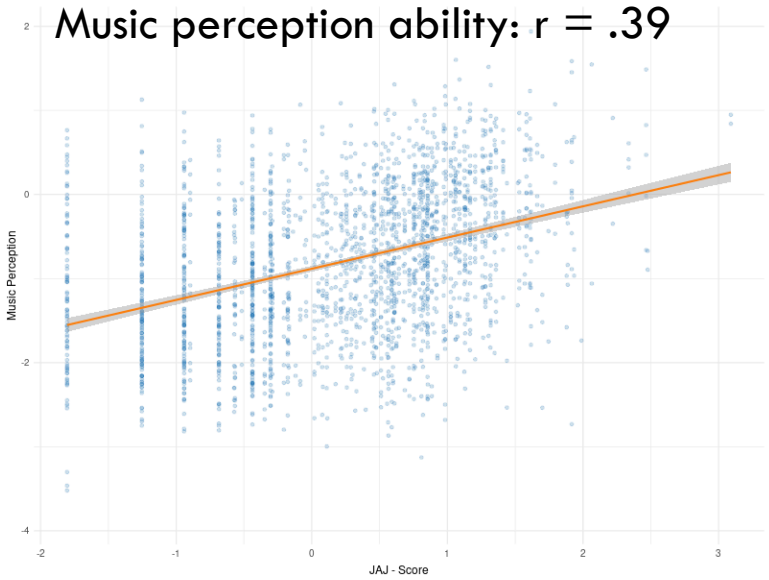
General Intelligence: r = .38



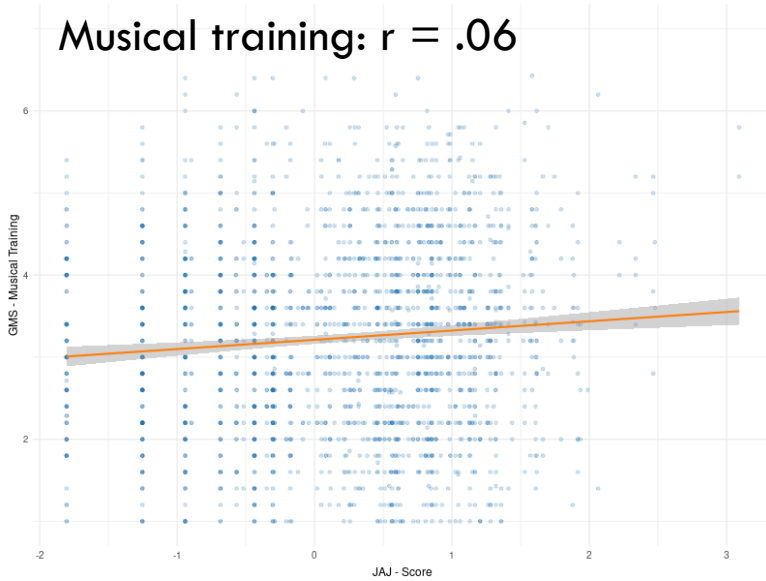
Academic performance: r = .19



Music perception ability: r = .39

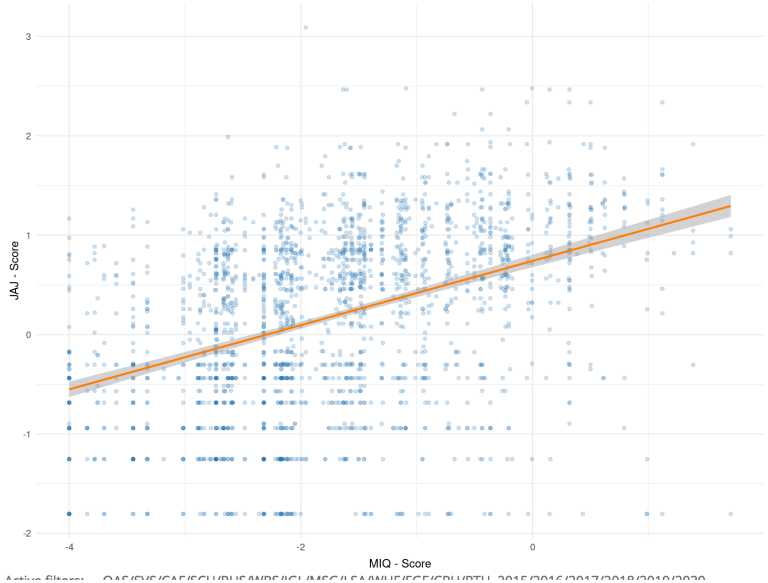


Musical training: r = .06

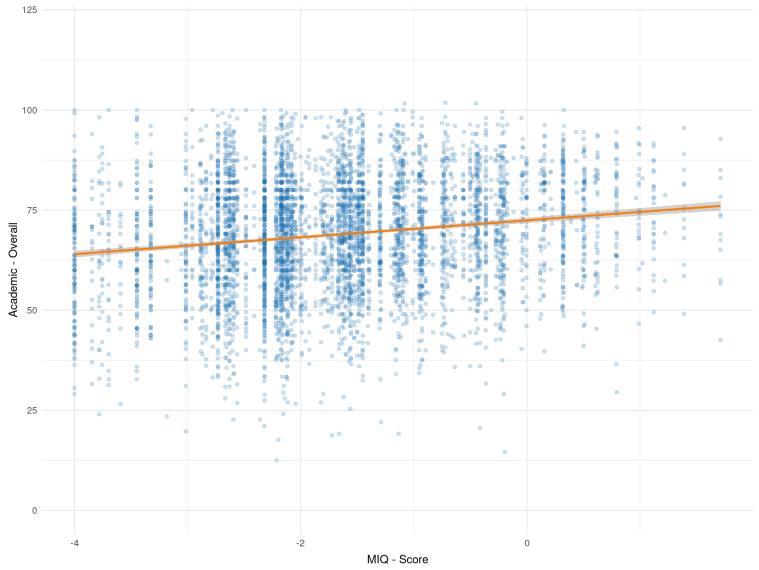


Intelligence correlates with

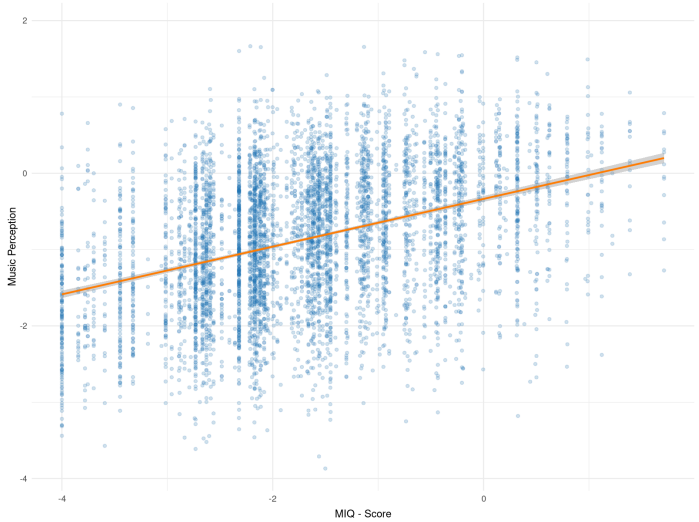
Working memory: r = .38



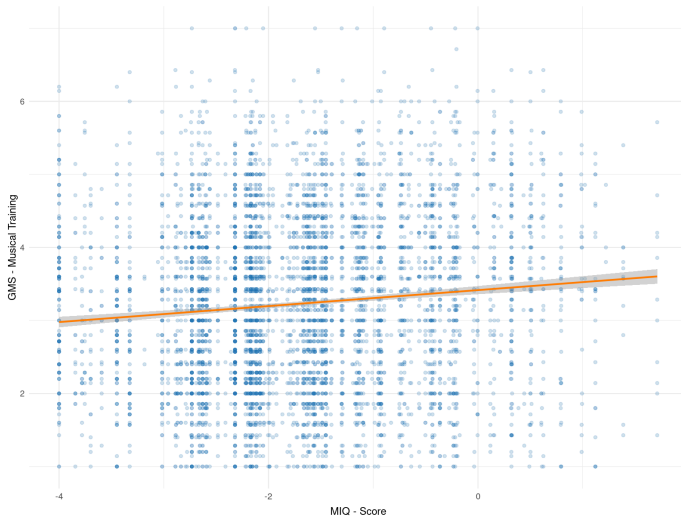
Academic performance: r = .16



Music perception ability: r = .43



Musical training: r = .09



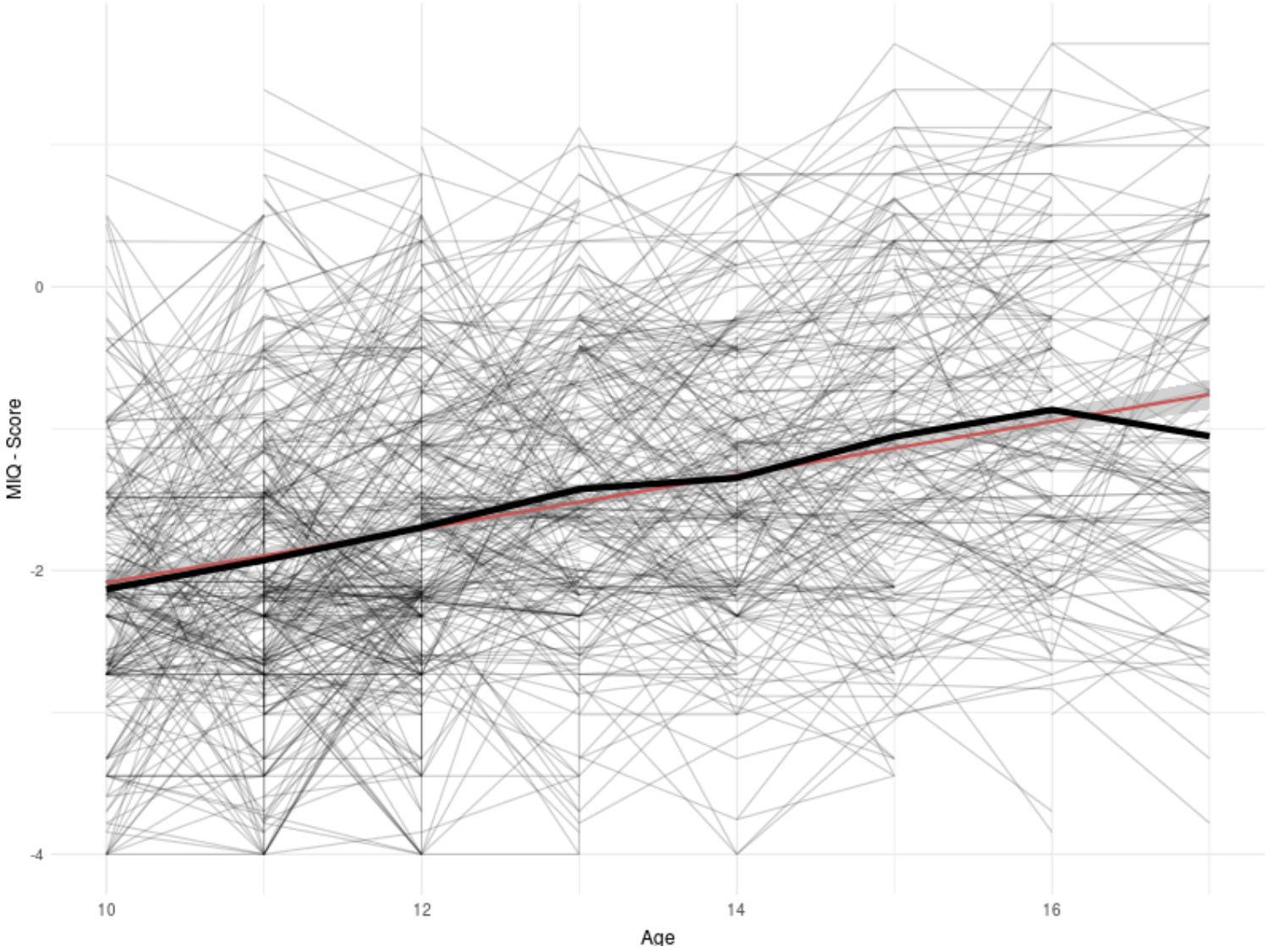
Analysing change in longitudinal data (McArdle & Nesslroade, 2014)

1. Intraindividual change
2. Individual differences in intraindividual change
3. Interrelations in behavioral change
4. Causes of intraindividual change

Intraindividual change

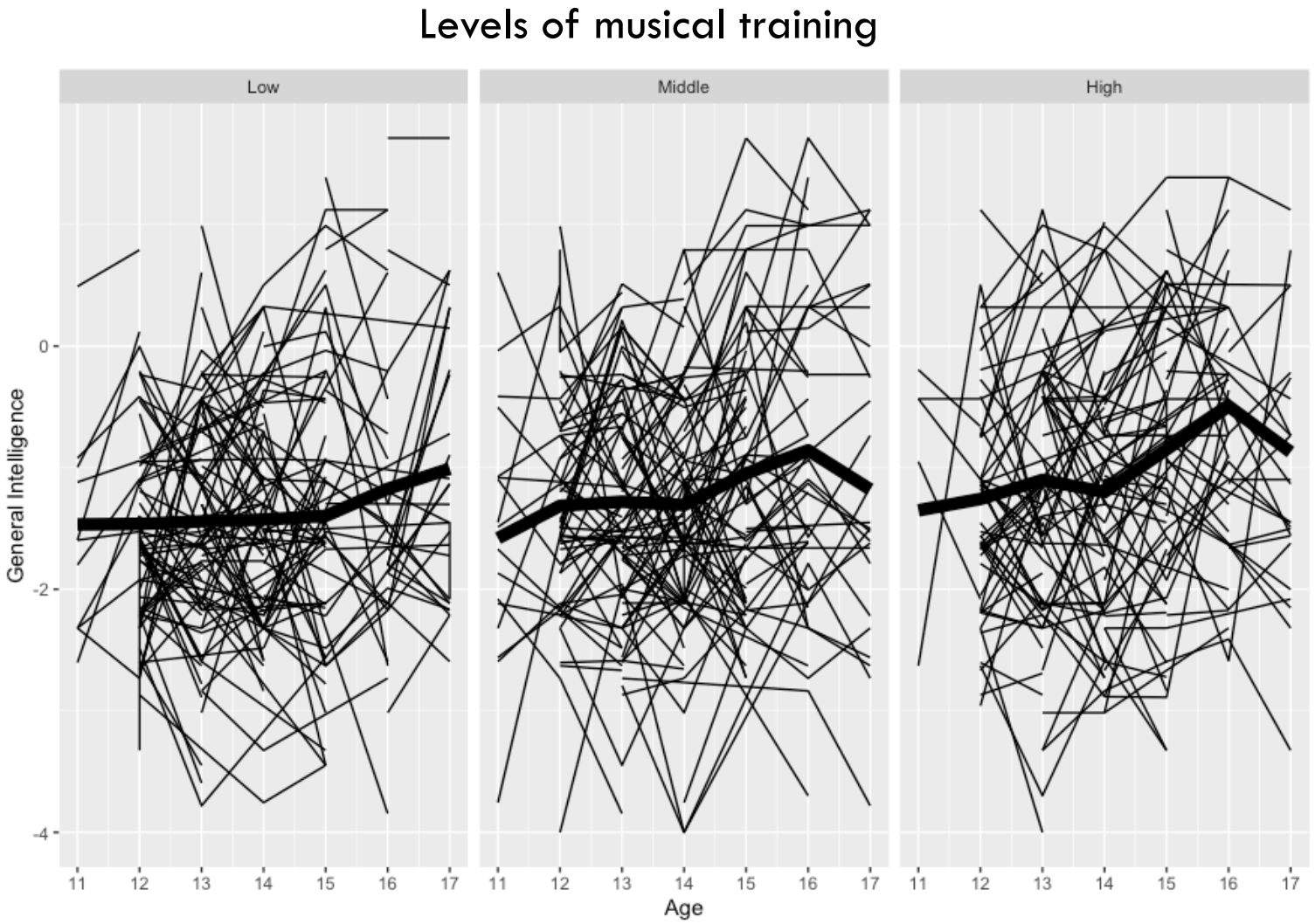
Intelligence grows with age

Growth rate is about 1/10 of a standard deviation per year (~ 1.5 IQ points/year)



Age and musical training contribute to intelligence test scores

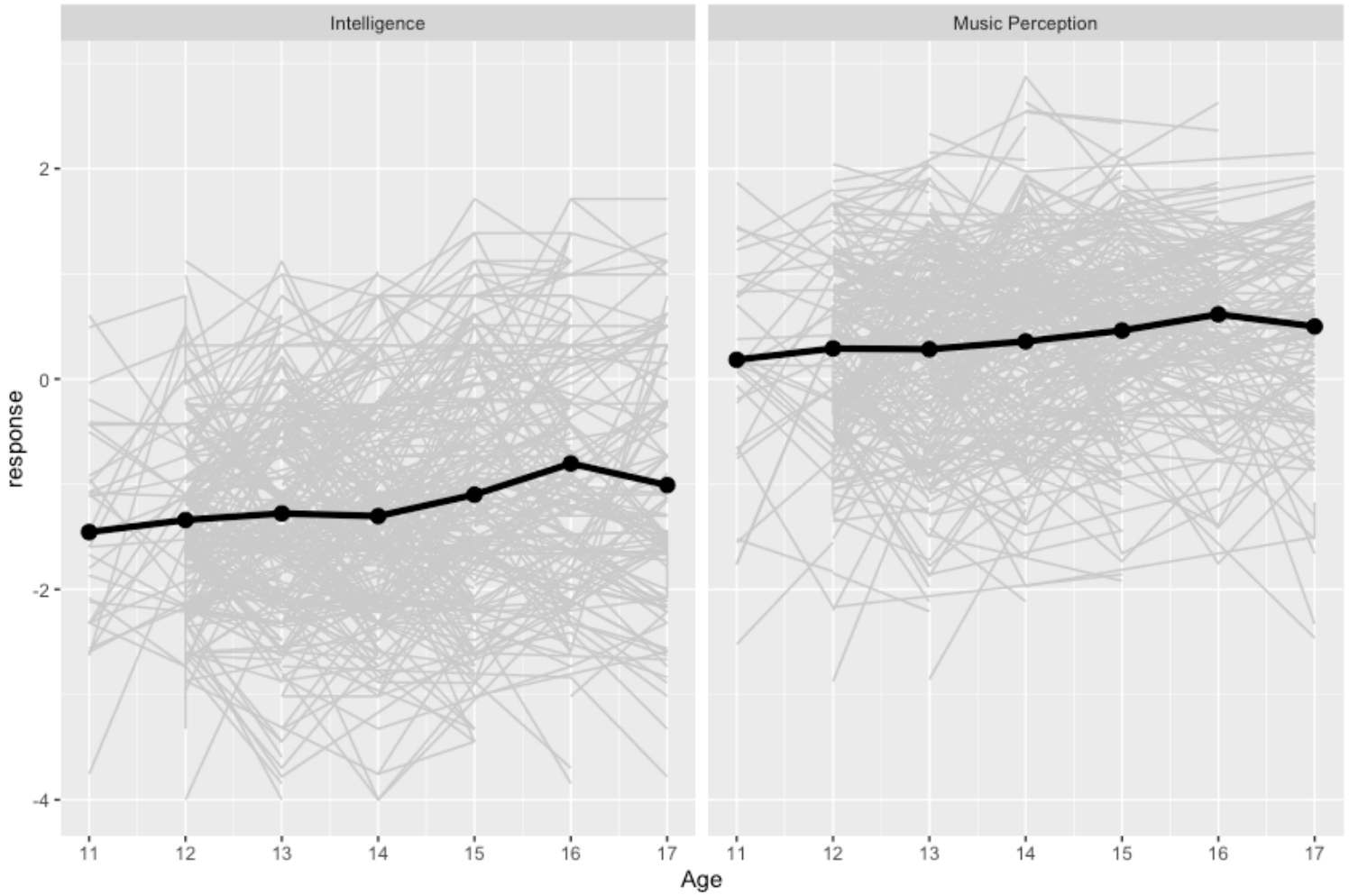
- Similar effect size for musical activity (standardized coefficient = 0.12) and age (standardized coefficient = 0.15)
- A higher intelligence growth rate for children with high v. low musical levels of musical training



Interrelations in behavioral change

Growth in intelligence and music perception ability are related

Intelligence and music perception abilities show very similar growth patterns, but they are not statistically identical.



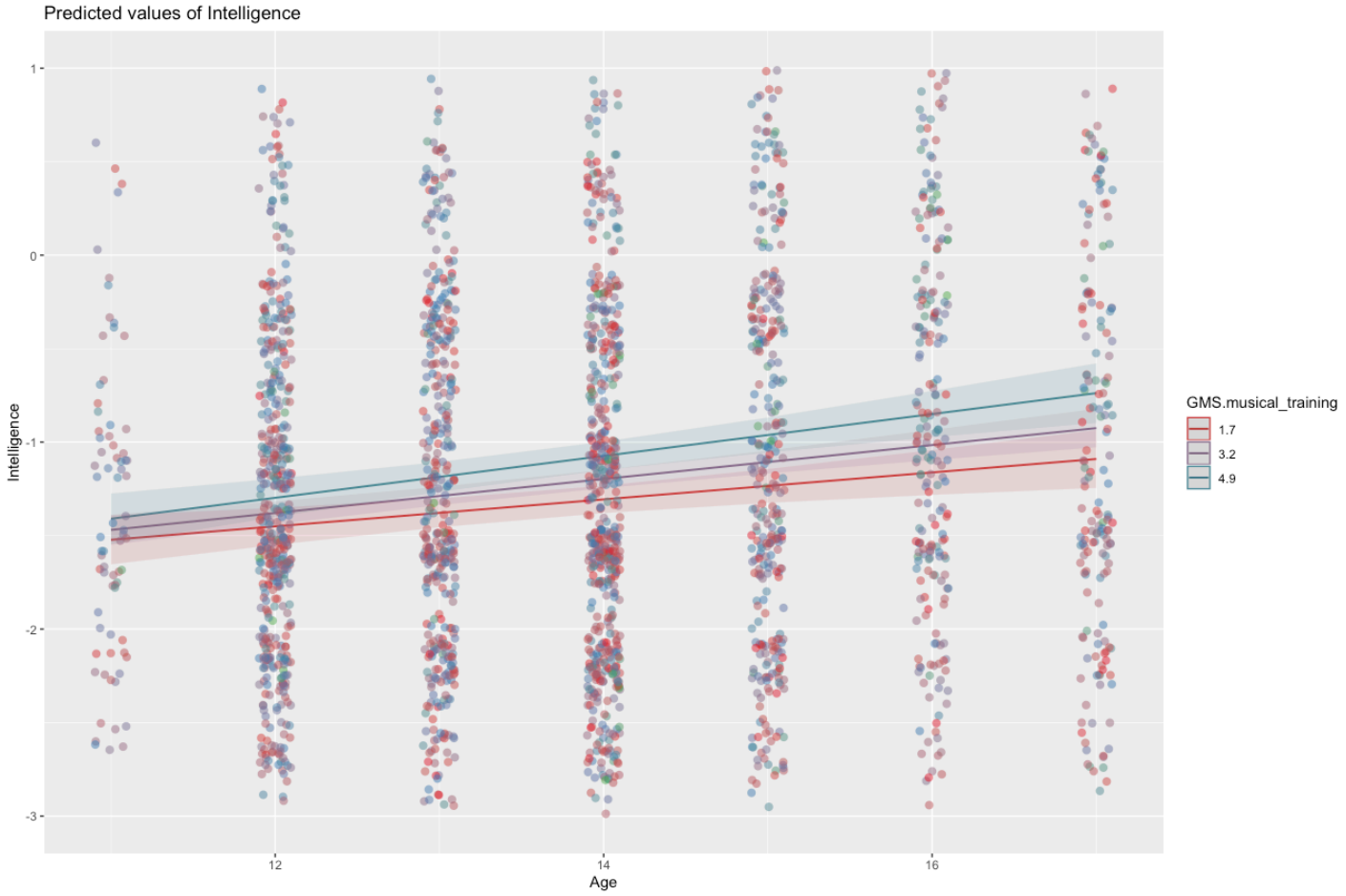
Causes of intraindividual change

Musical training interacts positively with growth in intelligence

Intelligence grows with age, but intelligence grows faster for pupils who receive more musical training

=> Musical training amplifies small differences in intelligence at age 11 into larger differences at age 17.

Small effect size: $\Delta R^2 \sim .01$



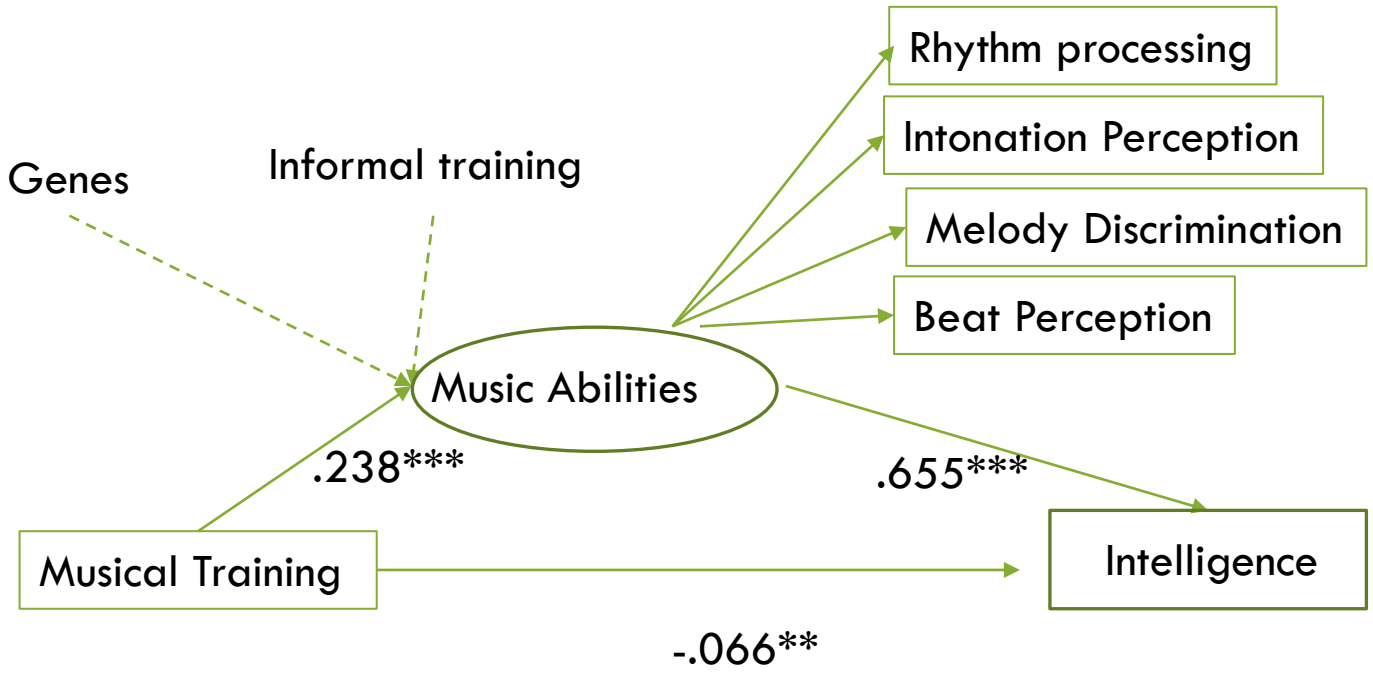
Summary

- Intelligence grows during teenage years
- Pattern of growth is similar for intelligence and musical abilities
- Higher levels of musical training are associated with higher intelligence scores
- The growth rates for intelligence are higher when more musical training is received

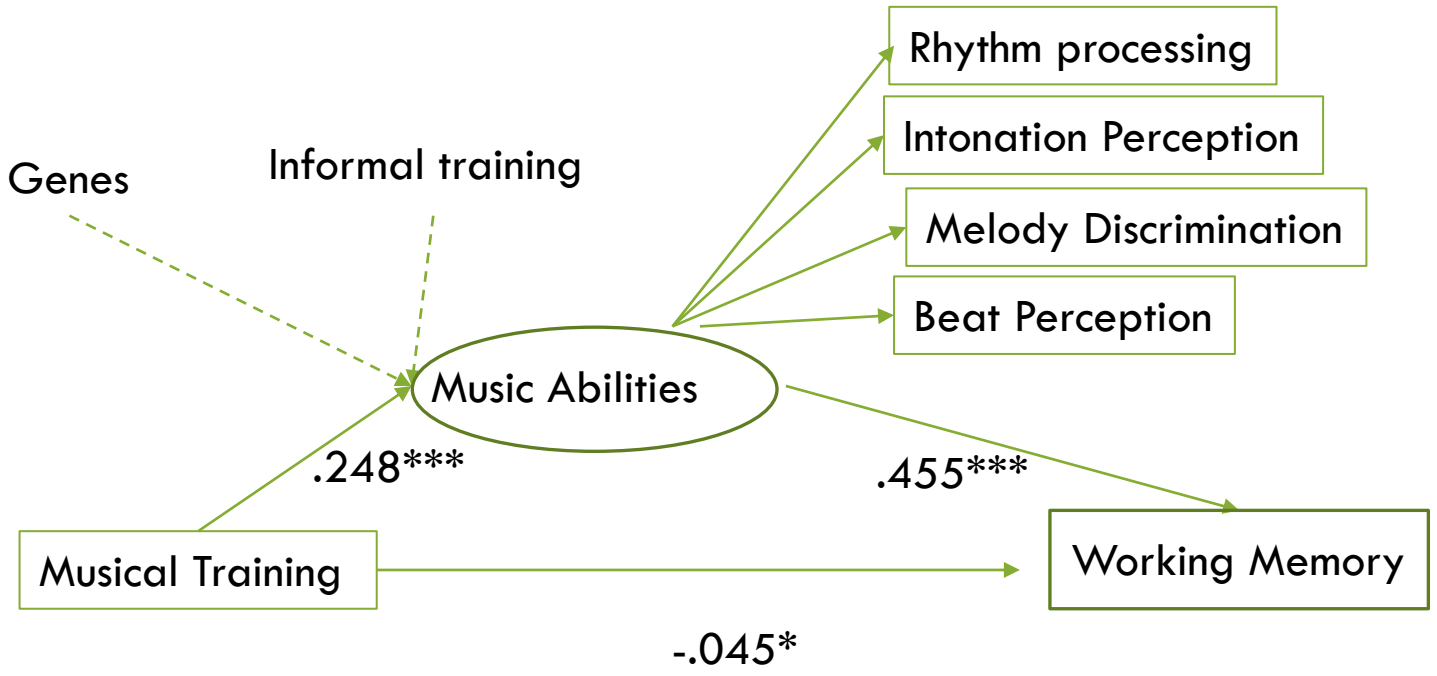
Next steps

- Replicate pattern of results with **working memory** as target variable
- Compare results with new data from ABCD study (J. Iverson)
- Address causality and consider the role of near transfer via musical abilities

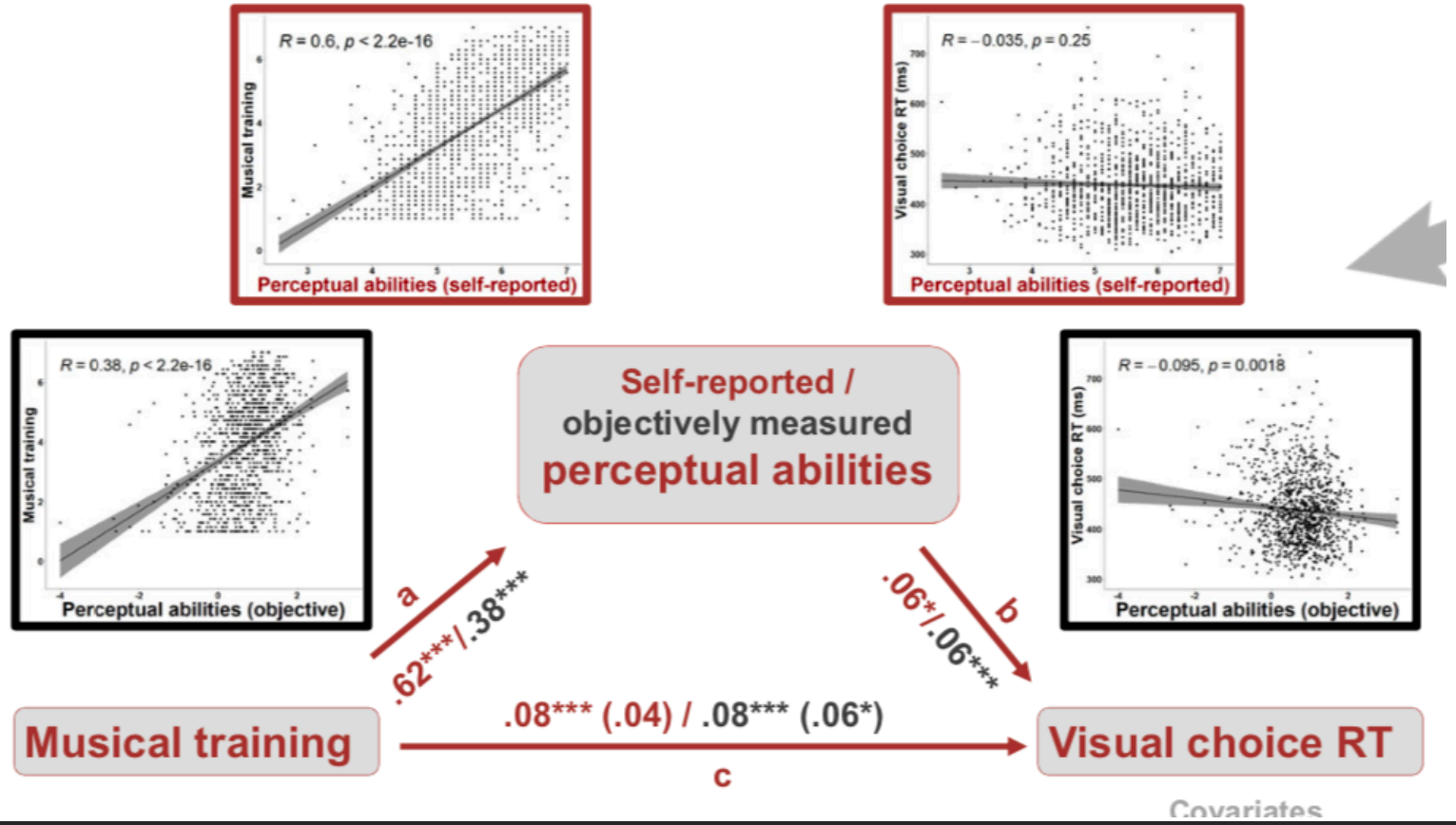
Positive effect of musical training on **intelligence** is fully mediated by music perception abilities



Effect of musical training on **working memory** is fully mediated by music perception abilities



Effect of musical training on **visual reaction time** is mediated by music perception abilities (Møller, Hansen, Vuust, & Müllensiefen, 2021)



Effect of musical training on **vocal emotion recognition** is fully mediated by music perception abilities (Correira et al., 2020)

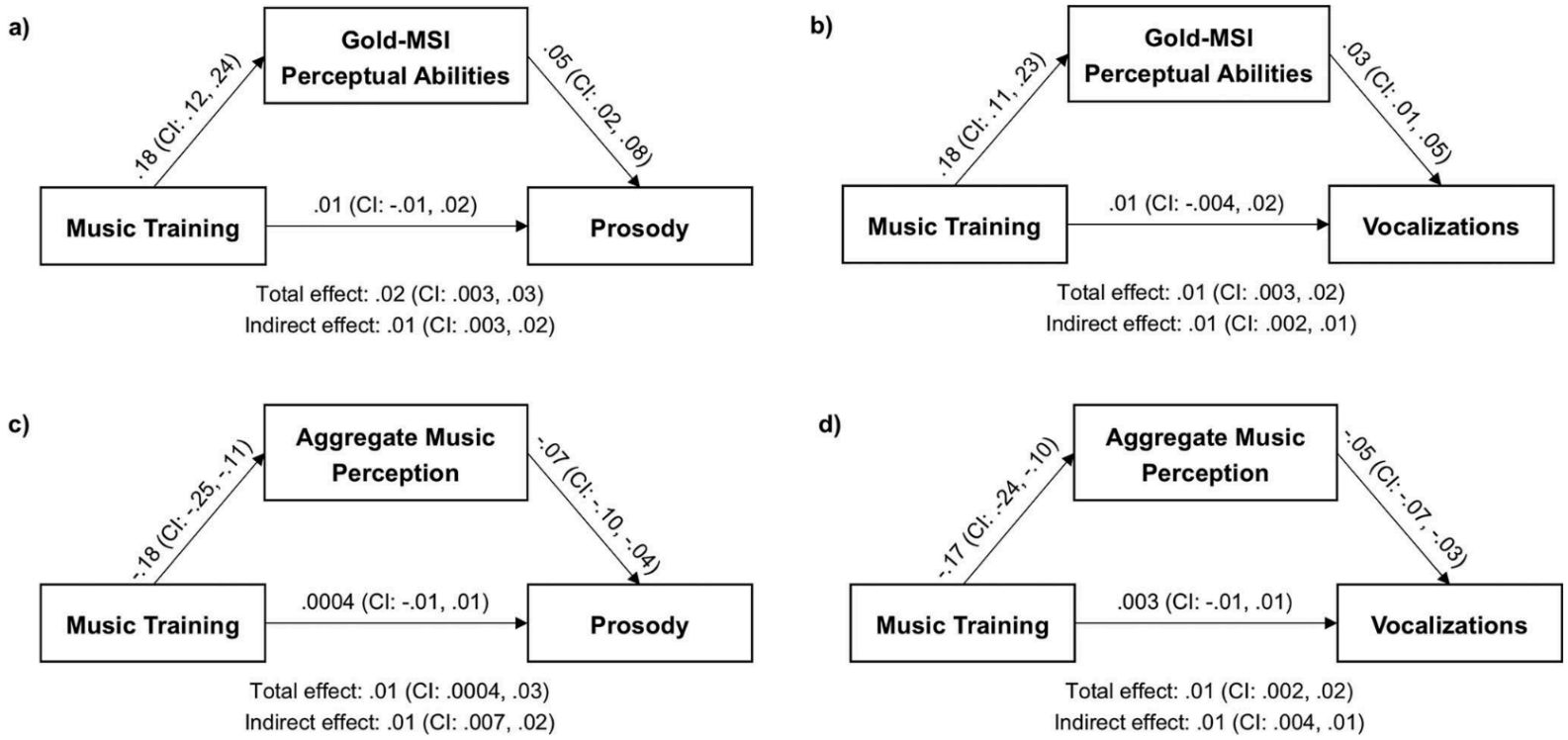


Figure 3. Models depicting the mediation effect of music perception abilities (Goldsmiths Musical Sophistication Index [Gold-MSI] Perceptual Abilities and Aggregate Music Perception) on the association between music training and vocal emotion recognition (prosody and vocalizations). Inference was based on percentile bootstrap 95% confidence intervals (CIs) with 20.000 samples. Lower scores in Aggregate Music Perception indicate better performance.

Take home message

- Music training only has far transfer effects on cognitive abilities if it also has near transfer effects

⇒Include musical ability tests in assessment battery

⇒Individual differences (due to genes, prior music skills, learning attitudes etc.) important for effect size of musical training