Are children who play a sport or a musical instrument better at motor imagery than children who do not?

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ABSTRACT

Objective Playing a sport or a musical instrument is presumed to improve motor ability. One would therefore predict that children who play a sport or music are better at motor imagery tasks, which rely on an intact cortical proprioceptive representation and precise motor planning, than children who do not. The authors tested this prediction.

Methods This study involved an online questionnaire and then a motor imagery task. The task measured the reaction time (RT) and the accuracy for left/right-hand judgements in children aged 5 to 17 years. Forty pictured hands (20 left), held in various positions and rotated zero, 90°, 180° or 270°, were displayed on a screen. Participants indicated whether the displayed hands were left or right by pressing keys on a keyboard.

Results Fifty-seven children (30 boys; mean±SD age=10±3.3 years) participated. The mean±SD RT was 3015.4±1330.0 ms and the accuracy was 73.9±16.6%. There was no difference in RT between children who played sport, music, neither or both (four-level one-way analysis of variance, $p=0.85$). There was no difference in accuracy between groups either (Kruskal–Wallis, $p=0.46$). In a secondary analysis, participants whose parents rated them as being 'clumsy' were no slower (n.s.) but were about 25% less accurate than those rated coordinated or very coordinated ($p<0.05$).

Conclusion The authors conclude against the intuitively sensible and widely held view that participation in a sport or music is associated with better cortical proprioceptive representation and motor planning. Secondary analyses suggest that parent-rated clumsiness is negatively related to motor imagery performance.

INTRODUCTION

It is widely held that participating in a sport or playing a musical instrument is good for a child's coordination.[1 2] Coordination depends on the coherent cortical proprioceptive representations, or 'maps', and accurate motor planning. It holds then that playing a sport or music would be associated with coherent cortical proprioceptive maps and accurate motor planning. However, assessing motor performance does not establish this. Therefore, the widely held view that playing a sport or music is good for coordination[2] seems to rely on the observation that playing a sport or music is good for playing sport or music. Sport and music are complex activities with many components, improvements of which would improve performance. For example, performance depends on the familiarity with rules, self-efficacy, cardiovascular fitness, concentration, practice, strength and endurance. As such, using performance to measure motor ability or coordination in general, and cortical proprioceptive representation and motor planning in particular, would seem problematic.

One way to get around this problem is to use motor imagery. The most established quantifiable assessment of motor imagery performance is the left/right judgements of pictured limbs – numerous studies have been undertaken in healthy people and those with neurological or musculoskeletal injury.[3–13] Left/right judgements can be considered implicit motor imagery, whereas imagined movements can be considered explicit motor imagery. Critically, the recognition of body parts involves fundamentally different mechanisms to the recognition of objects – the recognition of objects involves rotating the pictured object to match an internally held repertoire of objects, and the recognition of body parts involves manoeuvering one's own body to match the picture (see[14] for review).

There are two variables of interest: reaction time (RT), which is thought to reflect the central nervous system processing speed and attentional or expectation bias; and the accuracy, which is thought to reflect the precision of cortically held proprioceptive maps and motor planning.[8] The RT and accuracy of left/right-limb judgements allow us to interrogate the proprioception – motor system without the confounding effects of deficits related to executing the movement within a performance context – for example, biomechanical, social or environmental constraints – and the possibility of adopting a third-person perspective, which can be used for imagined movements and which is more consistent with the visual imagery than it is with motor imagery.

One group in whom it is particularly interesting to consider the cortical proprioceptive representation and motor planning is children. That children who play a sport or music have better motor ability than those who do neither is so widely accepted that it is seldom questioned. Of course, sport and music are not equivalent, but one might predict that children who play both will have particularly high motor ability. However, we suggest that this position is usually based on a circular argument – that playing a sport or music improves motor ability, as evidenced by playing a sport or music.

Little is known about left/right judgements in children. Although experiments have been done,[15–17] samples have been small and results have not been related to the participation in sport or music. The present study hypothesised that

left/right-hand judgements would be faster and more accurate in children who play a sport or music than in those who do not. We also hypothesised that RT and accuracy improve with age. Finally, because participation in a sport or music is not necessarily reflective of ability, a secondary, exploratory aim was to determine if parent-rated clumsiness, which provides an indirect measure of motor ability that is also dependent on contextual and social factors, is related to accuracy on left/right-hand judgements. We did not seek to identify interactive effects of parent-rated clumsiness and the participation in a sport or music on motor imagery performance.

METHODS

Participants aged 5 to 17 years were recruited for this cross-sectional online study by advertising through social media including Facebook, Twitter, the research group's blog (http://www.bodyinmind.org) and that of an international clinical education company (www.noigroup.com). Only participants who had access to the Internet were eligible. Human Research and Ethics Committee of the University of New South Wales granted ethics approval. All procedures conformed to the Declaration of Helsinki.

Protocol

After reading the information sheet and providing consent, participants completed a questionnaire that included demographic data and explicit questions about participation in sport and music, self-rated proficiency in sport and music and parent-rated coordination or clumsiness (supplementary table S1). They were then familiarised with the left/right judgement task using the online programme Recognise (http://www.recognise.noigroup.com/recognise/; noigroup.com, Adelaide, Australia). In this task, a photograph of a hand was shown on a computer monitor. Participants judged whether the hand was a left or a right hand and responded by pressing one of the two keys on the keyboard: the 'd' key for a right hand and the 'a' key for a left hand. Participants were told to use their index fingers to respond. Participants were asked to answer quickly, but not to guess. A response triggered the next photograph and the process was repeated. If no response was made in 15 s, the next photograph was shown. Each image and its response constituted a trial. There were 40 trials in a batch. Participants undertook two batches. Only the second batch was analysed. This left/right judgement protocol has been widely used in healthy[7 8 10 18] and clinical[7 11–13 19–22] adult populations.

Photographs of pictured hands

The bank of images is composed of 42 randomly oriented photographs of children's hands. There are two introductory images; one of a left hand and the other of a right hand, which served as calibration images. There were 40 remaining images, 20 were randomly selected as left hands and the other 20 were randomly selected as right hands. Ten were randomly selected with no rotation, then 10 were rotated by 90°, 10 were rotated by 180° and 10 were rotated by 270°. The reliability of online programme Recognise has been previously demonstrated by a large cross-sectional study with the 95% CI for all between-day repeatability intraclass correlation coefficients being >0.7 (supplementary file table S2).

Analyses

Participants were only included in the statistical analysis if they were healthy and under the age of 18 years. Participants were deemed healthy if according to their questionnaire responses they did not have any pain (acute or chronic), if they had no current medical conditions that might affect motor imagery performance, and were not taking medications. Descriptive analyses were undertaken on the participants' age, gender and participation in a sport or music. Only RTs for correct judgements were analysed, as per the recommendations in the literature.[3]

We expected accuracy data to be skewed, so Spearman's Rho was used to detect any trade-off between RT and accuracy, where a significant and negative Rho would indicate that accuracy declined as RT increased. All participants were grouped according to their responses to the questionnaire items about playing a musical instrument and playing a sport. The item about playing a musical instrument dichotomised the participants by offering a yes or a no response. The item about playing a sport gave the participants four options: 'no, I do not play any sport'; 'yes, I play a little bit'; 'yes, I play a fair amount of sport' and 'yes, I play a large amount of sport'. Participants were dichotomised into those who responded with 'no' or 'a little bit' or those who responded with either of the other options. This categorisation yielded four groups of broadly similar size: those who played an instrument but did not play a sport, those who played a sport but did not play an instrument, those who played an instrument and a sport, and those who played neither. To test the primary hypothesis, we undertook a univariate four-level analysis of variance on RT data and a Kruskal–Wallis non-parametric test for four independent samples on accuracy data. Our data satisfied the assumptions of our tests. To reduce the risk of wrongly rejecting the hypothesis, we undertook an independent sample's t test for RT and Mann–Whitney U test for accuracy for the two groups most likely to be different, according to our hypothesis: those who played neither a musical instrument nor a sport, and those who played both.

Because age might be associated with an increased likelihood of playing a sport or a musical instrument, we compared the four groups on age using a Kruskal–Wallis test for the independent samples, with a sensitive α=0.1. The statistical analyses were conducted with IBM SPSS Version 19.0.

RESULTS

Participants

Full datasets were obtained from 57 participants (31 girls), mean±SD age=11±3 years. Age and gender according to the group are shown in figure 1.

Response time and accuracy

RT data were normally distributed. The mean response time RT for healthy children was 3015.4±1330.0 ms. Accuracy data were not normally distributed. The median accuracy was 80.9%, IQR 59.5 to 88.0% (mean±SD=73.9±16.6%). The correlation between RT and accuracy was not significant, which indicates that there was no evidence of a speed-accuracy trade-off (Spearman's Rho, r=0.20; p=0.13).

The effect of age, gender and handedness on RT and accuracy

The relationship between age and RT was not significant (r=−0.20; p=0.14), but accuracy improved with age (Spearman's Rho, r=0.561; p<0.001). There was no effect of gender on RT (boys=2927±1407 ms; girls=3045±1269 ms; t=−0.33; p=0.74), nor on accuracy (median accuracy for boys=81.0%, IQR=59.5 to 88.1% and for girls=78.6%, IQR=57.1 to 88.1%;

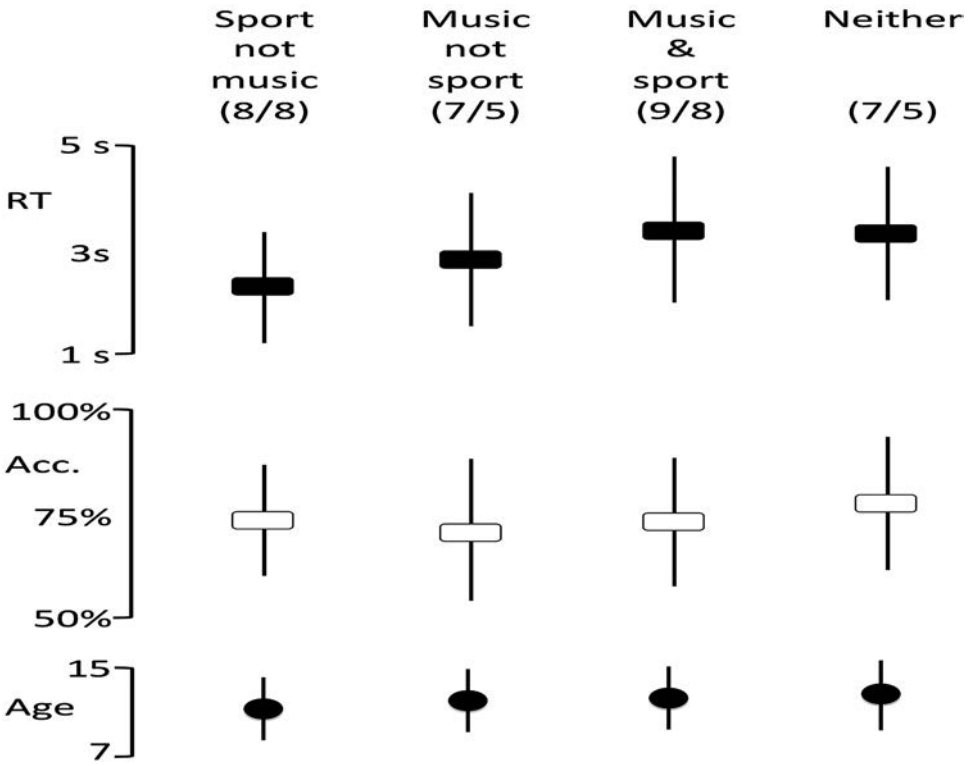

Figure 1 Mean and SD (error bars) reaction time (RT) (filled rectangles) and accuracy (Acc. open rectangles) for left/right judgements of pictured hands across the four groups of children who played a sport but not a musical instrument, a musical instrument but no sport. both or neither. The number of girls/boys in each group is shown in brackets. Mean (circles) and SD (error bars) age in years across groups are also shown.

Mann–Whitney U test; p=0.58). Age and gender distribution were similar across groups (figure 1; Kruskal–Wallis on age: p=0.63).

Is participation in a sport or music, or both, or neither, related to left/right judgement performance?

Whether or not children participated in a sport, or music, or both, or neither, did not relate to motor imagery performance (figure 1; Kruskal–Wallis, p=0.13 for RT and 0.84 for accuracy). The critical result that underpins the rejection of the hypothesis that participation in music or a sport is associated with improved motor imagery performance was the non-significant Mann–Whitney U test between children who played neither an instrument nor a sport, and children who played both (p=0.21 for RT and 0.65 for accuracy). There were insufficient responses to the questionnaire item about the self-rated proficiency in a sport to warrant analysis.

Secondary analysis – does motor performance relate to parent-rated clumsiness?

Those who reported that they were clumsy were not slower on the left/right judgements than those who reported that they were coordinated or very coordinated (t=−0.70; p=0.49). However, those who reported being clumsy were less accurate (median=55%, IQR=43 to 68%) than those who reported being coordinated (median=83%, IQR=73 to 93%) or very coordinated (median=90%, IQR=81 to 98%; Kruskal–Wallis, p=0.01).

DISCUSSION

We hypothesised that left/right-hand judgements would be faster and more accurate in children who play a sport or music than in those who play neither. Our results do not support this hypothesis – there was no difference in RT or accuracy between those who played a sport or music, or both, or neither. Sensitive statistical analysis upheld the main result – a lack of effect on the comparison of means. We also intended to determine whether the performance at left/right judgements improves with age, which it does. Finally, we undertook a secondary analysis to see whether parent-rated clumsiness was associated with the accuracy of left/right judgements, which it was – children rated as somewhat clumsy or clumsy were much less accurate at left/right-hand judgements than children rated as coordinated or very coordinated.

Our RT data are broadly consistent with and build upon the limited literature in this area, which suggests little or no effect of age on RT and a small effect towards increased accuracy with age.[15 16] One strength of the current study was a sample size that was much larger than the previous work in children, and had an even spread of participants between the youngest and the oldest participants. Although our main purpose was not to undertake a developmental study, our finding suggests that the cortical proprioceptive maps used for movement are still refining during childhood, a suggestion that would be predicted according to Caeyenbergh *et al*'s[15] hypothesis that young children are unable to support forward models of motor actions until about 10 years of age. Clear increases in motor performance,[23] and in fronto-parietal coupling,[24] also occur around this age. Taken together with the current data, it appears possible that motor performance limitations in children under 10 years old is due, at least in part, to the incomplete development of proprioceptive representation and motor planning, rather than biomechanical or structural constraints per se. Certainly, more developmental work appears warranted.

We found no effect of gender on RT or accuracy. This finding contrasts with the general picture from adult studies – men typically outperform women in spatial transformation tasks[14 25] and in left/right judgements of neck rotation (Wallwork *et al*, unpublished data). Some research has shown that gender differences in the spatial transformation of objects do not typically emerge until adolescence, and that these differences can then be attributed to the socio-cultural factors.[26] We did not see a difference between genders emerge in adolescence, although our sample may have been underpowered to detect such an effect.

Although previous small studies suggest that children who are diagnosed with developmental coordination disorder (DCD) are less able to mentally rotate images and body parts,[27 28] the current study is the first to investigate children who have not been diagnosed with any movement or coordination disorder, but whose parents rate them as 'clumsy'. Our results show that clumsy children were, on average, over 25% less accurate than the rest of the sample, a difference that reflects an effect size of about 1.2.

Our main finding does not support the intuitively sensible, and widely claimed idea,[1 2] that participating in a sport increases motor ability. Although an interventional study would be required to definitively demonstrate a lack of effect, the current data suggest that if motor performance does improve with participation in a sport, it is unlikely that it does so by refining the cortical proprioceptive maps or motor planning. Instead, improvement might be gained, for example, from improvements in strength, endurance, confidence or self-efficacy. Consistent with this line of thought, the current results raise the possibility that training aspects of motor performance that are 'upstream' from sport or music may offer the benefits in motor ability that are sought from participating in a sport. This might be particularly relevant for populations for whom a sport is difficult for logistic or health reasons. There are preliminary data to support this idea – children diagnosed with DCD were randomly allocated to a 5-week imagery-based programme, a conventional activity-based programme or a waiting list control group.[29] The imagery and conventional groups improved, but the control group did not. Visual imagery and third person imagery constituted the bulk of that imagery programme. Notably, however, visual and third person imageries are thought to involve the rotation of pictured objects or people to suit an internally held repertoire of objects, behaviours or postures.[14 30] In contrast, the left/right judgements rely on the mental rotations of one's own body to match the picture shown (which is why it is such an excellent tool for quantifying motor imagery performance). One might predict then that a programme of first person imagery would yield greater improvements in motor performance. Of course, this prediction remains to be tested.

A secondary but nonetheless important implication of the current work is that left/right judgements might by a useful contributor to the assessment of children who are thought to be clumsy. DCD is diagnosed according to DSM-4 (Diagnostic and Statistical Manual of Mental Disorders) criteria, which rely on the child being compared with 'what would be expected given the person's chronological age and measured intelligence'.[31] The ambiguity and inconsistency that is introduced by such a criterion and the need for new robust quantifiable assessments have been recognised for some time.[32] Although there are several assessments of gross motor performance that offer reliable data,[33] these tests are culturally and behaviourally influenced, which remains an obvious limitation. Moreover, they are time consuming and labour-intensive. Criticism of the primary self-report measure, the DCD-Q[34] include an unstable factor structure,[34] poor consistency between parents and teachers[35] and a lack of specificity for DCD as distinct from attention deficit disorder.[35] Left/right judgements would not be vulnerable to cultural or behavioural influences, they are not vulnerable to a third person (ie, visual) imagery, they yield precise outcome data and they can be undertaken easily and quickly online. Clearly, the potential advantages are considerable and further exploration of this possibility seems warranted.

In summary, we have shown that accuracy but not RT improves with age, particularly up to 10 years. Playing a sport or music was not associated with an advantage in the left/right judgement performance, which suggests that cortical proprioceptive maps and motor planning are no better in those who play a sport or music than in those who do not. This is surprising considering the widely held view that playing a sport or music improves motor ability. Our results also suggest new possibilities for the left/right judgements in the assessment and management of clumsy children.

Contributors Conceptual development: GLM, JM, AD, MM. Data collection: AD, NB, RM, MM. Data analysis: AD, JM, GLM. Interpretation: AD, NB, RM, MM, JM, GLM. Write-up: AD, JM, GLM.

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