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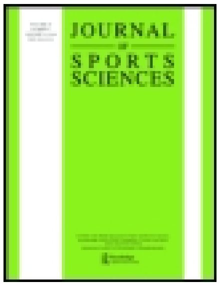

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Improving the TAMI for use with athletes

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Abstract

Athletes have been shown to have greater movement imagery abilities than non-athletes. However, since these differences were observed using questionnaires where participants subjectively judged the vividness of performing imagined movements, it is possible that responses could be biased by other factors such as social desirability. One possible solution is to use an objective test, such as the Test of Ability in Movement Imagery (TAMI; Madan, C. R., & Singhal, A. (2013). Introducing TAMI: An objective test of ability in movement imagery. *Journal of Motor Behavior, 45*, 153–166.). Unfortunately, young adults perform relatively well on the TAMI, leaving little room for statistical sensitivity in observing higher scores. Here we propose an alternate scoring method for the TAMI that resolves this limitation by weighing items according to their difficulty. We apply this scoring method to existing data and show that this improves the TAMI's selectivity to measuring ability in movement imagery, rather than related imagery processes. Thus, we have successfully improved the TAMI to be more suited for use with athletic populations.

Keywords: *movement imagery, athletes, mental imagery, vividness*

Introduction

It is well established that elite athletes have more efficient perceptual-motor skills than non-athletes, likely related to many factors, such as visual acuity (e.g., Ishigaki & Miyao, 1993), hand–eye coordination (e.g., Rodrigues, Vickers, & Williams, 2002) and musculature (e.g., Okamoto et al., 2012). Evidence also suggests that athletes possess superior abilities in imagining body movements, referred to as "movement imagery" (Madan & Singhal, 2012).

One way of quantifying this difference in efficiency is through movement imagery questionnaires, where participants are asked to imagine an instructed body movement and imagery ability is tested. Two of the most common tests of movement imagery are the Vividness of Movement Imagery Questionnaire (Isaac, Marks, & Russell, 1986; Roberts, Callow, Hardy, Markland, & Bringer, 2008) and the Movement Imagery Questionnaire (Gregg, Hall, & Butler, 2010; Hall & Pongrac, 1983). In these questionnaires, participants are asked to imagine a specified body movement and then subjectively rate how vivid the imagined action was.

Using these subjective measures, athletes have been shown to be better at imagining body movements (i.e., movement imagery) than non-athletes (Eton, Gilner, & Munz, 1998; Isaac & Marks, 1994; Roberts et al., 2008). Since these studies relied on subjective judgments, it is possible that responses could be biased by other subjective factors (MacIntyre, Moran, Collet, & Guillot, 2013; Madan & Singhal, 2013). To be more precise, it is likely that athletes do possess better movement imagery abilities than non-athletes. For instance, movement imagery training has been shown to improve athletic performance (Guillot, Nadrowska, & Collet, 2009; Olsson, Jonsson, & Nyberg, 2008; Robin et al., 2007; Schuster et al., 2011). However, the magnitude of this difference in movement imagery ability, as measured with subjective questionnaires, may be exaggerated. Providing some support for this notion, Allbutt, Ling, Rowley, and Shafiullah (2011) have reported significant correlations between measures of social desirability and measures of visual imagery. With specific regard to movement imagery, athletes may find it socially more favourable to respond that they can imagine movements with a high degree of vividness, whereas non-athletes' responses may not be as biased by these social factors. Similarly, motor skill confidence may also be exaggerated in athletes (e.g., Rattanakoses et al., 2009; Taylor & Shaw, 2002), leading to higher ratings on subjective

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questionnaires of movement imagery. That is, imagery of athletic outcomes (e.g., getting a hole-in-one) likely influences actual performance (Beilock, Afremow, Rabe, & Carr, 2001; Taylor & Shaw, 2002; Woolford, Parrish, & Murphy, 1985). In the case of athletes, there may be a bias in their subjective ratings of their own movement imagery ability due to the fact that they perform more successfully in the first place. An athlete may subjectively rate their imagery as higher than that of a non-athlete because the vividness of their imagery experience is actually linked to their performance outcome, which is also generally higher than that of a non-athlete. Thus, we suggest that there is particular value in a more objective measure of movement imagery for use with athletes, such as the recently developed TAMI (Madan & Singhal, 2013). The TAMI requires participants to make explicit imagined movements from an external perspective.

Specifically, participants are instructed to imagine a series of five specific body movements and then asked to select the final body positioning from several body-positioning images. Thus, there is a correct answer for each question on the TAMI, and it is not possible for scores to be biased by other factors. The TAMI consists of 10 questions, preceded by a practice question, and takes approximately 10 min to complete. Madan and Singhal (2013) demonstrated the validity of the TAMI by comparing it to other measures of mental imagery (see Table II) as well as measuring the test–retest reliability (2 week delay, $r = 0.71$).

In designing a novel objective measure, several choices had to be made that are important in delineating what the TAMI is and is not a measure of and how it compares to existing subjective and objective measures. For instance, the TAMI is based on imagining body movements, rather than the manipulation of abstract objects, as in the Mental Rotations Test (Vandenberg & Kuse, 1978). In fact, recent research suggests that the Mental Rotations Test does not index movement imagery ability, but instead measures dynamic visual imagery, likely due to the abstract nature of the Mental Rotations Test's stimuli (Annett, 1995; Madan & Singhal, 2012). The TAMI is based on general simple body movements, such as "Step your left foot forward 30 cm". In contrast, some other measures rely on basic action concepts (see Schack & Mechsner, 2006), such as "climbing a wall" (Vividness of Movement Imagery Questionnaire) or more specific actions that are confined to a particular sport, as in the Movement Imagery Specific Test (Moreau, Clerc, Mansy-Dannay, & Guerrien, 2010). The TAMI is also designed to assess movement imagery of gross body movements. In contrast, the Florida Praxis Imagery Questionnaire (Ochipa et al., 1997) asks participants to imagine specific hand/tool-related questions, as it is intended for patients with apraxia. By making these distinctions of what the TAMI is designed to measure, we are better able to assess how it relates to extant measures and determine which factors may or may not influence the TAMI.

The current version of the TAMI involves one fairly important limitation: healthy young adults perform relatively well on the TAMI, on average, scoring nearly 8 out of 10. This high score leaves little room for statistical sensitivity in observing significantly higher scores (i.e., a ceiling effect). Here, we propose an alternate scoring method for the TAMI that resolves this limitation and improves the overall utility of the test.

To illustrate this limitation quantitatively, consider if we predicted that a specific population would have enhanced movement imagery ability, such as athletes, relative to matched controls. A power analysis should be conducted to determine the necessary sample size. Based on the TAMI scores ($M = 7.56$; $s = 1.58$) obtained in Madan and Singhal (2013; combining Studies 1 and 2), we used G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the sample size, given the parameters: $\alpha = 0.05$, Power $(1 - \beta) = 0.75$. If we predict that athletes would have a mean TAMI score of 8.5 and have equal variance (Cohen's $d = 0.59$), we would need at least 36 athletes and 36 matched controls. If we assume a larger difference, such as a mean TAMI score of 9.0 ($d = 0.91$), we would need a more modest minimum of 16 participants per group. Nonetheless, here we are also hypothesising that the athletes will, on average, only make one incorrect response out of 10.

To solve this limitation, we took advantage of the fact that performance on the individual questions that comprise the TAMI was not consistent. In other words, participants found some questions to be more difficult than others, with mean accuracy on each of the 10 questions ranging from 38% to 95% (Table I; also see Table I of Madan & Singhal,

Table I. Assigned weight for each question in the TAMIw score.

Question	Performance (%)	Assigned weight
1	90	1
2	80	2
3	95	1
4	58	4
5	83	2
6	60	4
7	90	1
8	91	1
9	38	5
10	73	3

2013). Here we developed a new scoring procedure for the TAMI, where more difficult questions (i.e., those with lower mean accuracy) were weighted more heavily than relatively easier questions, rather than weighting all questions equally. Furthermore, we evaluated how this new TAMI-weighted (TAMIw) score correlates with other measures of mental imagery.

Methods

The materials and methods, including information about the participants, have been previously reported (Madan & Singhal, 2013). Here we summarise these sections briefly, and describe the new analyses that were conducted.

Participants

A total of 190 introductory psychology students (from both Studies 1 and 2 of Madan & Singhal, 2013) at the University of Alberta participated for partial fulfilment of course credit. To ensure adequate comprehension of the instructions, all participants were required to have learned English before the age of 6. Participants gave written informed consent prior to beginning the study, which was approved by a University of Alberta Research Ethics Board.

Measure

Test of ability in movement imagery (TAMI). The TAMI consists of 10 questions. Each question consisted of a sequence of 5 movements involving manipulations of the head, arm/hand, torso and leg/foot. All questions began with the instruction to “Stand up straight with your feet together and your hands at your sides”. One example of a movement instruction used in the TAMI is: “Step your left foot 30 cm backward”. Each set of movement instructions was followed by a set of 5 body-positioning images, along with the choices of “none of the above” and “unclear”.

Participants were first provided with a practice question. After choosing a response, they were provided with the correct answer and given the opportunity to flip back and reread the instructions, as well as to ask the experimenter for clarification. For the remaining 10 questions, participants were explicitly told that they could not flip back to the question’s instruction page after flipping to the response page. This restriction on flipping back was included to prevent participants from ruling out responses by simply rereading the question’s movement instructions.

Procedure

Participants completed the questionnaire independently, though the researcher administering the questionnaire was nearby to provide clarification if requested. The questionnaire required approximately 10 min to complete. Data from participants that flipped back to the instructions when answering a non-practice question were excluded from analyses ($n = 7$).

Data analysis and results

Developing the TAMIw score

Responses on the TAMI were scored as correct only if the participant chose the single correct answer, with no partial grades being awarded. With the original TAMI scoring method, TAMI scores could be any integer value between 0 and 10. Across both Studies 1 and 2 of Madan and Singhal (2013), participants’ mean TAMI score was 7.56 ($s = 1.58$). After combining participant data from both studies, participants’ performance on the TAMI did significantly deviate from a normal distribution ($JB(182) = 6.81$, $P < 0.05$), though this was not the case when data from either study was analysed independently. Figure 1A illustrates the distribution of participants’ TAMI scores.

As discussed in the introduction and demonstrated with the power analysis, this relatively high mean score leaves little room for athletes to perform statistically significantly better than non-athletes on the TAMI. To address this limitation, we assigned weights such that harder questions were worth more towards the final score than easier questions, and termed this scoring method the TAMIw score. Difficulty was assessed using the average performance on each questions (i.e., harder questions were those with poorer performance). Questions’ weights were determined by identifying clusters in performance, as shown in Figure 2. Clusters were identified by sorting the performance scores for each question, calculating the difference between the scores (i.e., the highest minus the second highest, the second highest minus the third highest, etc.), and determining where the largest score differences (“gaps”) are, while still aiming to minimise the total number of clusters. Importantly, the gap between the clusters was required to be larger than the width of the cluster (i.e., spread). This clustering approach was additionally formally validated using the Ordering Points to Identify the Clustering Structure (OPTICS) cluster analysis method (Ankerst, Breunig, Kriegel, & Sanders, 1999; Daszykowski, Walczak, & Massart, 2002).

Questions with the highest performance (questions 1, 3, 7 and 8) were assigned a weight of 1

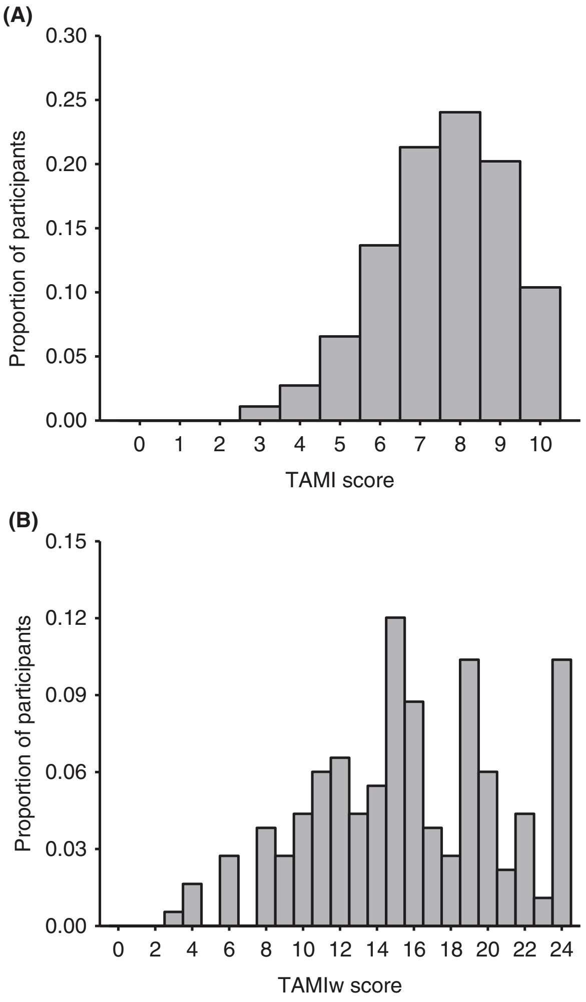

Figure 1. Distribution of participants' scores using the (A) TAMI score and (B) TAMIw score.

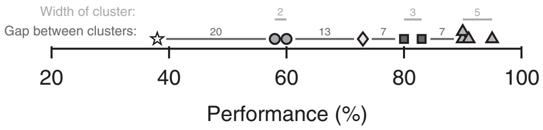

Figure 2. Distribution of questions' performance. Each marker denotes a single question, with different colours and shapes used for each cluster (i.e., assigned weighting). The width of cluster represents the difference between the highest and lowest scores within a cluster. The gap between clusters represents the difference between the lowest score from one cluster with the highest score of the adjacent cluster. Also see Table I.

and the cluster spanned a width of 5%. This cluster was followed by a gap of 7% between the lowest scoring question in this first cluster (90%; questions 1 and 7) and the next highest scoring question (83%; question 5). Questions in the second cluster were assigned a weight of 2 and spanned a width of 3%, followed by a between-cluster gap of 7%. Question 10 was assigned a weight of 3, and followed by a gap of 13%. Questions 4 and 6 comprised the fourth cluster and were each assigned a weight of 4. This cluster spanned 2% and was followed by a between-cluster gap of 20%. Question 7 was assigned a weight of 5.

See Table I for a summary of the question's accuracy and assigned weight for the TAMIw score. The maximum TAMIw score is 24.

Applying this alternate scoring method to the data obtained in Madan and Singhal (2013), participants' mean TAMIw score was 15.70 [$s = 5.10$] and is no longer near the upper limit of the scale. Participants' performance on the TAMIw did not significantly deviate from a normal distribution ($JB(182) = 3.41$, $P > 0.1$). Figure 1B illustrates the distribution of participants' TAMIw scores.

Note that a TAMI score of 9 out of 10 could convert into a TAMIw score between 19 and 23 out of 24. However, a TAMI score of 10/10 would convert into a TAMIw score of 24/24, as all questions were answered correctly. For this reason, the proportion of participants with a TAMI score of 10 (see Figure 1A), which was 10%, is the same as the proportion of participants with a TAMIw score of 24 (see Figure 1B).

Correlations with other measures

In Study 2 of Madan and Singhal (2013), participants were administered the TAMI along with a number of other measures including: the Florida Praxis Imagery Questionnaire (Ochipa et al., 1997), the Vividness of Movement Imagery Questionnaire, revised version (Roberts et al., 2008), the Vividness of Visual Imagery Questionnaire (Marks, 1973), the Mental Rotations Test (Peters et al., 1995; Vandenberg & Kuse, 1978), and a modified version of the Corsi block-tapping task (Corsi, 1972; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000). See Madan and Singhal (2013) for detailed descriptions of each questionnaire.

The goal of administering these other measures was to test for common variability between the TAMI and other measures, in the form of correlation analyses, to see if common cognitive processes support performance in both tasks. Using our new TAMIw scoring method, we can again test this question, to determine if the TAMIw score provides additional sensitivity than the original TAMI score. All of the correlations are listed in Table II. The column with correlations with the TAMI score is as reported in Madan and Singhal (2013).

Comparing the correlations using the TAMI and TAMIw scores, one result becomes apparent: The TAMIw score is more sensitive to movement imagery, rather than other similar processes. Correlations with the internal visual imagery subscale of the Vividness of Movement Imagery Questionnaire and the position subscale of the

Table II. Correlation with the TAMI and TAMIw scores for all measures from Study 2 of Madan and Singhal (2013). All correlations use the TAMI administered in the same experimental session.

	TAMI	TAMIw
VMIQ2-IV[a]	0.36*	0.37*
VMIQ2-EV[a]	0.24	0.25
VMIQ2-Kin[a]	0.05	0.08
FPIQ-Pos	0.45**	0.44**
FPIQ-Act	0.39*	0.19
FPIQ-Obj	0.34*	0.13
FPIQ-Kin	0.24	0.15
MRT	0.15	0.16
VVIQ[a]	0.43**	0.32†
modCorsi-Span	−0.20	−0.10
modCorsi-Prod	−0.09	0.08

Notes: TAMI, test of ability in movement imagery; TAMIw, TAMI-weighted; VMIQ2, Vividness of Movement Imagery Questionnaire, revised version; VMIQ2-IV, VMIQ2 internal visual imagery subscale; VMIQ2-EV, VMIQ2 external visual imagery subscale; VMIQ2-Kin, VMIQ2 kinaesthetic imagery subscale; FPIQ, Florida Praxis Imagery Questionnaire; FPIQ-Pos, FPIQ position subscale; FPIQ-Act, FPIQ action subscale; FPIQ-Obj, FPIQ object subscale; FPIQ-Kin, FPIQ kinaesthetic subscale; MRT, mental rotations test; VVIQ, Vividness of Visual Imagery Questionnaire; modCorsi, modified Corsi block-tapping task. $^{\dagger}P < 0.1$; $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; [a]In the VMIQ2 and VVIQ, lower scores correspond to better imagery. Correlations with VMIQ2 and VVIQ are sign-adjusted such that a positive correlation indicates a better score on both measures.

Florida Praxis Imagery Questionnaire remain significant and unaffected by the change in scoring methods. However, correlations with the action and object subscales of the Florida Praxis Imagery Questionnaire are no longer significant, and the correlation with the Vividness of Visual Imagery Questionnaire is attenuated, when using the weighted score rather than the original score.

Discussion

Here we sought to improve the TAMI by reducing ceiling effects and making it more applicable for use with athletic populations. We did this by creating an alternative scoring method, the TAMIw score, that weighs the relatively difficult questions more heavily in the final score, rather than weighing all questions equally. The results of the new TAMIw scoring suggest that ceiling effects are no longer a problem; thus, we achieved our main goal. Furthermore, while we focused on improving the TAMI's sensitivity to enhancements of movement imagery, a secondary aim was to improve the TAMI's sensitivity to measuring individual movement imagery ability. We were successful in this as well and found that the new scoring method more specifically correlates with similar tests of movement imagery compared to other types of related imagery processes. Together, these two results further strengthen the TAMI's role as a novel, objective test of movement imagery ability, through the newly developed TAMIw scoring method.

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