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SHORT REPORT

No sex differences in the TAMI

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Abstract The Test of Ability in Movement Imagery (TAMI; Madan and Singhal in J Mot Behav 45:153–166, 2013) has recently been developed as an objective measure for evaluating individual ability in movement imagery. Other tests of imagery have reported sex differences, including the mental rotations test (MRT) and the Vividness of Movement Imagery Questionnaire (VMIQ). However, some have attributed these observed sex differences to other processes, such as difference in spatial abilities and confidence. Here, we tested for sex differences in the TAMI in a large sample of young adults ($N = 246$). In the same sample, we also administered a modified version of the MRT that included both block configurations and human figures and the VMIQ2. This modified MRT was used, as the imagery processes involved in the TAMI may be more similar to those involved in the rotations of human figures. While strong sex differences were found in both subscales of the modified MRT, no sex differences were observed in the TAMI.

Keywords Movement imagery · Sex differences · Mental rotations · Mental imagery

Introduction

Motor movements are an important part of how we interact with the world around us (Wolpert et al. 2001). Related to this, an individual's ability to imagine motor movements should be related to their ability to process and execute these movements. Recently, the Test of Ability in Movement Imagery (TAMI; Madan and Singhal 2013) has been developed as an objective measure for evaluating individual ability in movement imagery. While this novel test shows promise, it is unclear whether there are any sex differences in the TAMI, as have been observed in other tests of mental imagery. It is additionally plausible that sex differences may be observed in the TAMI since the body-positioning responses in the TAMI use a female form, possibly leading to a congruity bias with the female participants.

A common test of mental imagery is the mental rotations test (MRT), initially developed by Shepard and Metzler (1971). In this test, participants are shown images of abstract 3D block configurations and have to determine whether they represent the same configuration from a rotated perspective or different configurations. Evidence suggests that the MRT is not a measure of movement imagery, but rather of dynamic visual imagery (Annett 1995; Madan and Singhal 2012; Munzert et al. 2009). Many studies have shown sex differences in MRT performance, with males outperforming females (Parsons et al. 2004; Peters et al. 1995; Richardson 1994; Vandenberg and Kuse 1978; Voyer et al. 1995; Voyer 2011). Currently, there is evidence that a sex differences exist in a variety of spatial tasks, particularly when visuospatial working memory is hypothesized to be involved (Coluccia and Louse 2004; Linn and Petersen 1985).

Alexander and Evardone (2008) recently developed a modified MRT that incorporates human figures along with block configurations. Alexander and Evardone found that the sex differences observed in the MRT were attenuated, but still significant, when using the human figures (also see Jansen and Lehmann 2013). Since the human figures are

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more similar to the TAMI than the block configurations in the standard MRT, this variant of the MRT can serve as an important intermediate between the standard MRT and the TAMI. For instance, several studies have rotation of hand images to activate primary motor cortex while block configuration MRT did not (e.g., Ganis et al. 2000; Tomasino et al. 2005a, b; also see Madan and Singhal 2012). Here, we predict that the processes involved in the human figure MRT should be more similar to the TAMI than the standard MRT with the TAMI. Thus, we predict the magnitude of a sex difference effect in the TAMI to be more similar to the hand figure MRT, which is attenuated relative to the standard MRT (Alexander and Evardone 2008).

We also included the Vividness of Movement Imagery Questionnaire, revised version (VMIQ2) in the current study (Roberts et al. 2008). The VMIQ2 asks participants to imagine prototypical motor movements (e.g., "running") and judge how vivid the imagined movements felt and thus is a subjective measure of movement imagery ability. The VMIQ2 consists of three subscales: internal visual imagery, external visual imagery, and kinesthetic imagery. Sex differences in the original version of the VMIQ have been previously found, but are not as well known as those found with the MRT. In the original version of the VMIQ, females were found to outperform males (Campos and Pérez 1988; Isaac and Marks 1994). However, Ashton and White (1980) found evidence that females may not be evoking more vivid imagery than males, but may instead have a response bias to subjectively report their mental imagery as being more vivid. In light of this, testing the VMIQ2 in the context of objective mental imagery tests, i.e., the MRT and the TAMI, may attenuate this bias. On the other hand, if females are evoking more vivid mental imagery when performing the VMIQ2, this sex difference should be present regardless of the other tasks that are in the same context as the VMIQ2.

In the current study, we administered the TAMI, modified MRT (blocks and humans), and VMIQ2 in a large sample of young adults. We evaluated performance for sex differences in all three questionnaires. We also examined the distribution of scores in the TAMI.

Methods

Participants

Two hundred and forty-six introductory psychology students [mean (SD) age = 19.2 (2.5); 124 female; 223 right handed] at the University of Alberta participated for partial fulfillment of course credit. All participants were required to have learned English before the age of six. Participants gave written informed consent prior to beginning the study, which was approved by a University of Alberta Research Ethics Board.

Measures

Test of Ability in Movement Imagery (TAMI)

Each question in the TAMI consists of a sequence of five movements involving manipulations of the head, arm/hand, torso, and leg/foot. The first movement instruction is always to "Stand up straight with your feet together and your hands at your sides." One example of the type of instructions used in the TAMI is as follows: "Step your left foot 30 cm backward." Each set of movement instructions was followed by a set of five body-positioning images, along with the choices of "none of the above" and "unclear." The TAMI consists of ten questions in total, preceded by a practice question. The practice question is shown in Fig. 1. For the practice question, participants were provided with the correct answer and given the opportunity to flip back and re-read the instructions, as well as to ask the experimenter for clarification. For the remaining ten 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 re-reading the question's movement instructions.

Madan and Singhal (2014) developed an alternative scoring method for the TAMI that placed greater weight on questions that were observed to be more difficult, termed the TAMIw score. Here, we scored the TAMI using both methods and also re-evaluated the validity of this alternate scoring method.

Mental rotations test (MRT)

The MRT requires participants to compare abstract 3D block configurations and determine whether they are the same, but rotated, or are different configurations (Shepard and Metzler 1971). In the pencil-and-paper version, the participant is presented with an exemplar image and four choice images, two of which are identical to the example configuration but rotated, while the other two images are based off of different configurations. For the answer to be correct, the participant must identify the two identical configurations.

Here, we used the modified MRT from Alexander and Evardone (2008), which is based on the MRT-A from Peters et al. (1995; re-drawn from Vandenberg and Kuse 1978). The modified MRT consisted of 23 questions, preceded by four practice questions: 11 of the items were identical to those from the MRT-A; the remaining 12 items

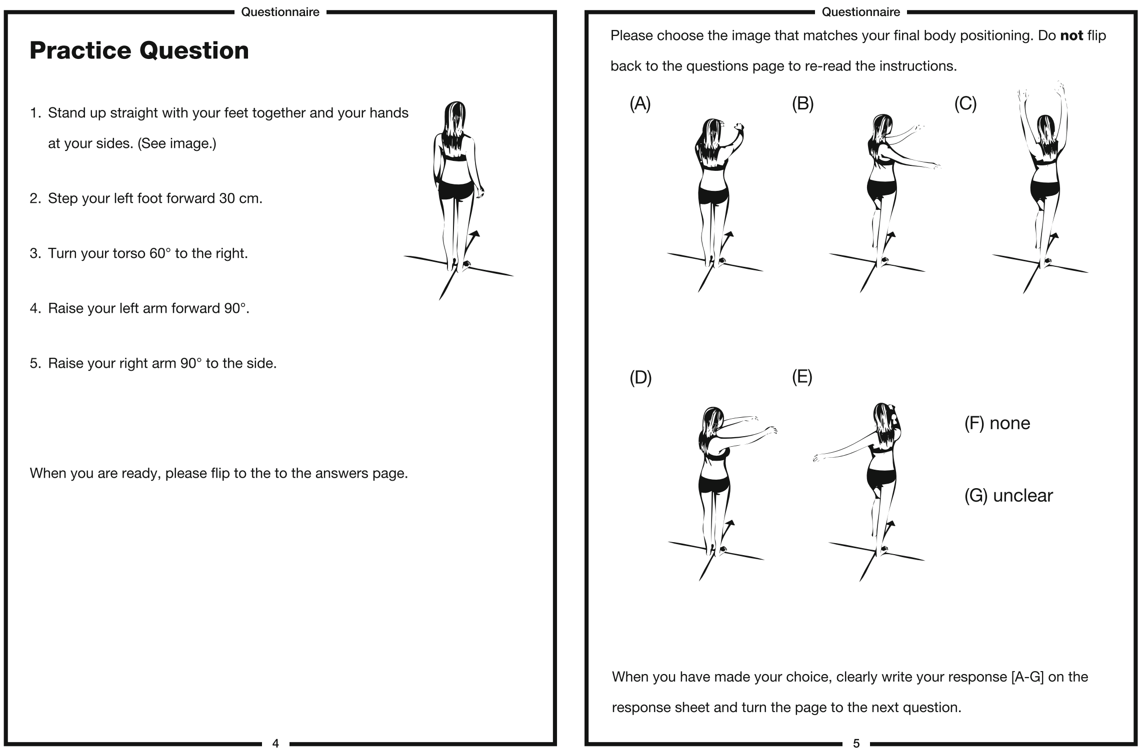

Fig. 1 Instructions and potential answers for the practice question of the TAMI

were human figures (six males and six females, wearing identical clothing). This modified MRT alternates between block and human questions.

Vividness of Movement Imagery Questionnaire, revised version (VMIQ2)

The VMIQ2 consists of 12 items, each describing a prototypical movement (e.g., "running," "walking," and "throwing a stone into water"). Participants are asked to imagine each of these movements using three types of imagery (i.e., subscales): external visual imagery (EV), internal visual imagery (IV), and kinesthetic imagery (K). For each movement and imagery type, participants rate the vividness of the imagined movement on a 5-point Likert scale, where a rating of "1" corresponds to the clearest and most vivid image. In external visual imagery, participants were asked to imagine themselves performing the movement from an external point of view. In internal visual imagery, they were asked to imagine the movement from an internal point of view, as if they were looking out through their own eyes while performing the movement. In kinesthetic imagery, the participants were asked to imagine themselves feeling doing the movement. See Roberts et al. (2008) for further details.

The VMIQ2 has several important differences relative to the original VMIQ (Isaac et al. 1986). Most critically, the original VMIQ only had two subscales, self and other imagery ("doing it yourself" and "watching somebody else," respectively). The VMIQ2 refined the instructions to specify internal and external visual imagery, as well as added the subscale for kinesthetic imagery. Additionally, the VMIQ2 made minor changes to the response method (writing a number in a blank vs. circling a number) to decrease the likelihood that participants got confused about the rating scale.

Procedure

All three questionnaires were administered in a single experimental session, with the order of the tasks pseudorandomized. Participants were given as much time as they needed to complete each of the tasks, with most participants taking 10–15 min per task.

Note that most studies of the MRT provide strict time deadlines (3-min task, 2-min break, and 3-min task; e.g., Alexander and Evardone 2008; Peters et al. 1995), though this is not always done (see Voyer 2011). Due to the demanding nature of the multiple tasks used in our study, we did not enforce a strict time limit.

Data analysis

One participant had all four limbs amputated and was also excluded from analysis. Sex difference statistics were computed with the assumption of unequal variances.

One participant was excluded for flipping back while completing the TAMI questionnaire, and their TAMI score was treated as a missing value. One participant did not complete the TAMI, and their score was also treated missing.

Missing or incomplete responses (i.e., only one option selected) in the MRT were treated as incorrect.

In the VMIQ2, if only one response was missing per subscale, this value was filled in as the average of the remaining 14 responses. If more responses were missing, the score was treated as a missing value ($N = 1$).

Results

TAMI

The mean (SD) TAMI score was 7.81 (1.59), and the distribution of the scores was highly skewed [JB(244) = 48.53, $p < .001$]. Using the TAMIw scoring method, the mean score was 16.51 (4.90), and the distribution was still significantly skewed, but much less so [JB(244) = 7.84, $p = .025$]. Thus, the TAMIw scoring method does improve the distributional characteristics of the TAMI scores, making them more suitable for parametric statistics such as t tests. Both of these distributions are shown in Fig. 2 (Table 1).

Madan and Singhal (2014) proposed an alternative method for scoring the TAMI that put a greater weight on the more difficult questions. As shown in Table 2, we computed the mean performance for each question in our large sample and found similar levels of performance for each question as was found previously. Given that mean performance was consistent between each of these large samples, 183 participants from Madan and Singhal (2013) and 245 participants from the current study, this adds further support to the validity of this alternate scoring method based on mean performance.

In the final sample, we had 123 females and 120 males who completed the TAMI. Using either scoring method, we found no sex difference in TAMI performance [TAMI: $t(238) = 1.14$, $p = .25$, $M_{female} = 7.69$ (1.52), $M_{male} = 7.93$ (1.66); TAMIw: $t(234) = 1.41$, $p = .13$, $M_{female} = 16.04$ (4.51), $M_{male} = 16.99$ (5.26)].

MRT and VMIQ2

In addition to the TAMI, we had five additional measures, two from the MRT and three from the VMIQ2. Mean (SD) scores from these measures are shown in Table 1.

In the MRT, we observed strong sex differences in both subscales: In the MRT-block, males scored 25 % higher than females [$t(223) = 6.83$, $p < .001$, $M_{female} = 5.97$ (3.68), $M_{male} = 8.76$ (2.63)]. In the MRT-human, we observed a strong, but less pronounced, difference with males scoring 14 % higher than females [$t(225) = 4.01$, $p < .001$, $M_{female} = 8.46$ (3.54), $M_{male} = 10.04$ (2.57)]. We also observed a main effect of task type, with participants performing better on the MRT-human than the MRT-block [$F(1,243) = 120.13$, $p < .001$].

In the VMIQ2, participants had marginally lower scores for external visual imagery than for internal visual imagery and kinesthetic imagery, as has been previously reported

Table 1 Descriptive statistics for the three questionnaires

Measure	Mean	SD	Range	
			Possible	Observed
TAMI	7.81	1.59	0–10	2–10
TAMIw	16.51	4.90	0–24	2–24
MRT-block	7.35	3.49	0–11	0–11
MRT-human	9.24	3.19	0–12	0–12
VMIQ2-IV	23.10	9.65	60–12	60–12
VMIQ2-EV	28.00	10.92	60–12	60–12
VMIQ2-K	24.02	9.52	60–12	57–12

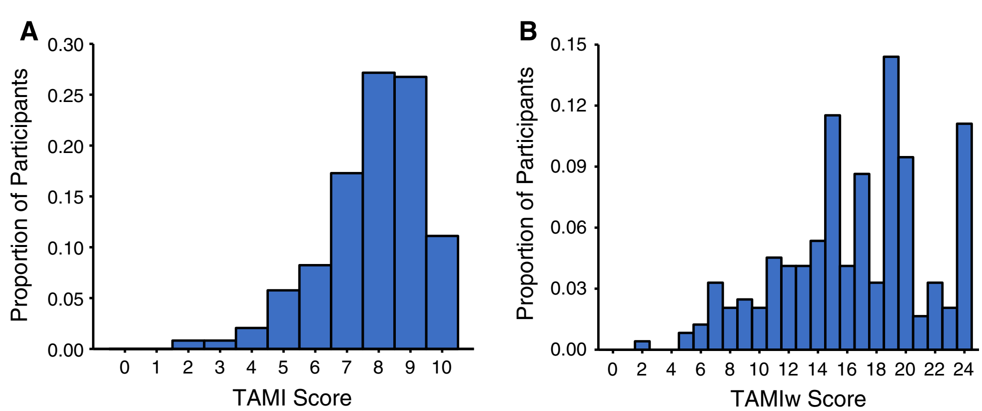

Fig. 2 Distribution of participants' **a** TAMI and **b** TAMIw scores

Table 2 Assigned weight for each question in the TAMIw score and the mean performance found in Madan and Singhal (2013) and the current study

Question	Assigned weight	Accuracy	
		Madan and Singhal (2013) (%)	Current study (%)
1	1	90	93
2	2	80	85
3	1	95	96
4	4	58	58
5	2	83	81
6	4	60	66
7	1	90	89
8	1	91	88
9	5	38	43
10	3	73	78

See Madan and Singhal (2014) for further details

(e.g., Madan and Singhal 2013; Roberts et al. 2008). Here, we observed sex differences in internal visual imagery subscale [$t(241) = 2.18$, $p = .031$, $M_{female} = 24.42$ (9.88), $M_{male} = 21.76$ (9.24)]. Sex differences in the other two subscales were not significant [both p's $> .1$].

Testing for sex differences in the TAMI using other movement imagery measures as covariates

Given that we found significant sex differences in the MRT and VMIQ, it is possible that including these measures as covariates in an ANCOVA may allow us to detect a sex difference in the TAMI by accounting for additional variability. Specifically, we constructed an ANCOVA with the TAMIw score as the dependent variable, sex as the independent variable, and the MRT and VMIQ2 subscales as covariates (MRT-human, MRT-block, VMIQ2-IV, VMIQ2-EV, and VMIQ-K). All main effects were included in the model, as well as all two-way interactions that included sex, to allow for the best chance of a sex difference to present. Neither the main effect of sex [$F(1,230) = .06, p = .81$], nor any of the interactions, was significant.

General discussion

Here, we administered the TAMI, MRT, and VMIQ2 and evaluated for sex differences in each measure in a large sample of young adults. We did not observe sex differences in the TAMI, but found strong sex differences in both the block configurations and human figures in the MRT. In addition to testing for sex differences in our large sample, we were also able to re-evaluate the alternate TAMIw scoring method and found a large degree of convergence.

It is well known that males perform better in the MRT, and this is usually attributed to sex differences in spatial ability. However, the cause behind this difference is not known (Voyer et al. 1995). Hooven et al. (unpublished) found that the sex differences were not related to the rotation component of the MRT and is instead related to differences in confidence in the decision process. Nonetheless, given that we did not find sex differences in the TAMI, it is unlikely that the factors driving the sex difference in the MRT are ones that overlap with the imagery processes in the TAMI.

In the modified MRT, Alexander and Evardone (2008) suggested a potential influence of emotional arousal in improving performance for the female human figures in male participants. However, the figures in the TAMI are dressed modestly than those in the modified MRT, and we observed no sex differences, suggesting that this was not a factor in the processes contributing to accurate performance in the TAMI.

The lack of a sex difference in the TAMI additionally provides important insights into the cognitive processes underlying the TAMI. Specifically, there is a significant body of evidence, suggesting that sex differences exist in visuospatial working memory (VSWM) (Coluccia and Louse 2004; Linn and Petersen 1985; Voyer et al. 1995). Given that the TAMI does not present a sex difference, this suggests that performance on the TAMI does not covary with these facets of VSWM that are related to sex differences. This is not to say that performance on the TAMI does not utilize VSWM, but rather that the TAMI does not relate to inter-individual differences in VSWM ability. Corroborating this notion, an earlier study of the TAMI found that performance on the TAMI did not correlate with performance on a modified Corsi block-tapping task (Madan and Singhal 2013, 2014). Further research is needed in order to determine the mediating imagery processes necessary for successful performance on the TAMI.

Previous studies have found sex differences in the VMIQ, with females performing better (Campos and Pérez 1988; Isaac and Marks 1994). Several studies using vividness measures to evaluate mental imagery, but not movement imagery, have similarly found better performance for females than males (e.g., Ashton and White 1980; Isaac and Marks 1994; McKelvie 1986). Ashton and White (1980) note that this sex difference may not be in the vividness of mental imagery per se, but may instead be an interaction of sex with the instrument itself, hinting at the subjectivity involved in all measures of vividness. In other words, mental imagery may not be more vivid for females than males, but females may instead have a response bias to report their mental imagery as more vivid. This type of interaction would not be possible in the TAMI, due to it being an objective scale. When comparing with prior observations of sex differences in the VMIQ, it is important to note that here we used the VMIQ2, which does involve a small modification where participants circled their response number, rather than writing it on a blank (Roberts et al. 2008). Here, we observed better performance for males than females in the internal visual imagery subscale and no sex difference in the other two subscales. It is possible that this could be attributed to the small difference relative to the VMIQ. However, it is more likely that this is due to a context effect where both the TAMI and MRT are objective tests of mental imagery (i.e., there are correct answers), and the administration of the VMIQ2 within this context attenuated subjective factors in the VMIQ2, such as sex-related differences in the subjective report of vividness. This is not to say that vividness ratings are uninformative as a measure themselves. For instance, there is evidence that vividness ratings do correspond to differences in neural processing, as Olivetti Belardinelli et al. (2009) demonstrated in an fMRI study. However, this study only tested females and thus cannot shed any light on possible sex differences in brain activity associated with vividness.

In sum, we did not find any evidence of sex differences in the TAMI. Given that prior findings of sex differences in the MRT and VMIQ are attributed to properties of the task that are distinct from the movement imagery itself, this suggests that there may not be sex differences in movement imagery and that the TAMI is a less biased measure of these processes. As a result, if evaluating differences between populations that also differ in sex (e.g., male and female athletes or patients), the TAMI may be a more appropriate measure since it is not susceptible to sex differences itself. Even if sex is not systematically varied between populations, it appears that it would not significantly influence performance on the TAMI, thus making the two groups easier to match.

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