

# **Movement Imagery Ability: Development and Assessment of a Revised Version of the Vividness of Movement Imagery Questionnaire**

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The purpose of this research was to amend the Vividness of Movement Imagery Questionnaire (VMIQ; Isaac, Marks, & Russell, 1986) in line with contemporary imagery modality and perspective conceptualizations, and to test the validity of the amended questionnaire (i.e., the VMIQ-2). Study 1 had 351 athletes complete the 3-factor (internal visual imagery, external visual imagery, and kinesthetic imagery) 24-item VMIQ-2. Following single-factor confirmatory factor analyses and item deletion, a 12-item version was subject to correlated traits / correlated uniqueness (CTCU) analysis. An acceptable fit was revealed. Study 2 used a different sample of 355 athletes. The CTCU analysis confirmed the factorial validity of the 12-item VMIQ-2. In Study 3, the concurrent and construct validity of the VMIQ-2 was supported. Taken together, the results of the 3 studies provide preliminary support for the revised VMIQ-2 as a psychometrically valid questionnaire.

*Keywords:* imagery ability, internal visual imagery, external visual imagery, kinesthetic imagery, correlated traits / correlated uniqueness analysis

Mental imagery is a central element in human functioning. For example, imagery is involved in the planning and execution of goal-directed movements (Jeannerod, 2001; Jeannerod & Jacob, 2005) and facilitates motor learning and performance (e.g., Driskell, Copper, & Moran, 1994). Imagery is proposed as a building block of conscious experience (Marks, 1999) and has been implicated within working memory (Bywaters, Andrade, & Turpin, 2004). Across these areas of functioning, individual differences in imagery ability underlie the effectiveness of imagery (e.g., Isaac & Marks, 1994; Mantani, Okamoto, Shirao, Okada, & Yamawaki, 2005).

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Two key characteristics of imagery ability are vividness and controllability (Callow & Hardy, 2005; Start & Richardson, 1964). Imagery ability is often measured via introspective reports of the vividness (i.e., the clarity and realism) of imagery experiences through validated questionnaires. Within the sport domain, one of the most commonly used questionnaires is the Vividness of Movement Imagery Questionnaire (VMIQ; Isaac, Marks, & Russell, 1986). The VMIQ is designed to measure visual and kinesthetic imagery of a variety of motor tasks (e.g., running downhill and jumping off a high wall).

When the VMIQ has been used in imagery research, it has captured the theoretically proposed effects of imagery ability. For example, differences in neural activation, in terms of electroencephalographic (EEG) activity, have been demonstrated between vivid and nonvivid imagers when imaging tasks from the VMIQ (Marks & Isaac, 1995). Behavioral research (e.g., Isaac, 1992) has demonstrated a moderating effect of vividness on motor performance, with greater performance improvements for participants reporting more vivid imagery. Differences in VMIQ scores have also been obtained between high- and low-level athletes, with high-level athletes reporting more vivid imagery (Eton, Gilner, & Munz, 1998; Isaac & Marks, 1994). Further to this, intervention studies (e.g., Hardy & Callow, 1999; Smith & Holmes, 2004) have shown effects on sport performance when specific vividness criteria on the VMIQ have been set as a preintervention requirement. In addition, the psychometric performance of the VMIQ has been shown to be acceptable, with test-retest reliability and concurrent validity being established (Isaac et al., 1986), and high internal consistency values reported (e.g., Lequerica, Rapport, Axelrod, Telmet, & Whitman, 2002).

Even though this research supports the use and validity of the VMIQ, and therefore imagery vividness as a measure of imagery ability, it is worth noting that using vividness to assess imagery ability has been criticized. Indeed, Dean and Morris (2003) suggest that there is no a priori reason for choosing vividness to measure imagery ability. They propose that imagery is a collection of abilities (namely, image formation, maintenance, and transformation; Kosslyn, 1994), rather than a single ability, and that the functional role of imagery in spatial ability tests is unrelated to imagery vividness. Although the suggestions of Dean and Morris concerning vividness have some legitimacy, it is worth noting that their argument relates specifically to spatial ability tests, as opposed to motor tasks (where the ability to create vivid images is important for performance; see Isaac, 1992, and Smith & Holmes, 2004). Furthermore, it makes intuitive sense to suggest that vividness could, at least to some extent, reflect the processes of formation, maintenance, and transformation, especially when the role of working memory in imagery vividness is considered. Image generation (formation) processes are activated by long-term memory, and image maintenance processes by working memory resources (see Ranganath, 2006). The vividness of a resulting image reflects the richness of the representation displayed in working memory (Baddeley & Andrade, 2000) and is likely to be a result of such processes as formation, maintenance, and transformation.

Because vividness does appear to capture imagery ability effects, the present authors disagree with the Dean and Morris (2003) position that imagery vividness is not an appropriate way to measure imagery ability. However, for three reasons, we feel that the VMIQ should be reexamined to improve it as a measure of imagery

ability. First, there has been confused conceptualization within the imagery literature between the visual imagery modality (i.e., what an imager sees) and the kinesthetic imagery modality (i.e., imaging the feel of the movement). This confusion has perpetuated into the VMIQ. To expand, Hardy and colleagues (Hardy, 1997; Hardy & Callow, 1999; White & Hardy, 1995) have proposed that the confusion between the visual and kinesthetic modalities stems from different interpretations of Mahoney and Avener's (1977) definition of "internal" imagery. Specifically, Mahoney and Avener propose that internal imagery is "an approximation of the real life phenomenology such that a person actually imagines being inside his/her body and experiencing those sensations that might be expected in the actual situation" (p. 137). Because this definition refers to the imager "being inside his or her body" and "experiencing those sensations," internal imagery could be interpreted as either the kinesthetic modality or the visual modality (i.e., first-person visual imagery; IVI), or a combination of both (Hardy, 1997). Similarly, in the VMIQ, the kinesthetic component requires participants to imagine *doing* movements *themselves*, with no explicit instruction to use the kinesthetic modality and not the visual modality. The ambiguity surrounding this conceptualization is not surprising, as in some cases IVI and kinesthetic imagery are viewed as always occurring together in so-called motor imagery. Indeed, based on Jeannerod's (1994) original work, motor imagery has been defined as "introspective kinesthetic feelings of moving the limb in a first-person view" (Lotze & Halsband, 2006, p. 389). This requires the combined use of internal visual imagery and kinesthetic imagery. However, this definition fails to delineate between modalities, which is vital especially because kinesthetic imagery can affect performance over and above the effects of visual imagery (Hardy & Callow, 1999). This does not mean that the two modalities cannot be used together; indeed they can (e.g., Glisky, Williams, & Kihlstrom, 1996); rather, it is important that the modalities *can* be measured separately, thereby making it possible to examine their differential effects. Further, a recent investigation using transcranial magnetic stimulation supports this separation, as differences in corticospinal activity between first-person visual imagery (i.e., IVI) and kinesthetic imagery have been obtained (Fourkas, Ionta, & Aglioti, 2006). Given that IVI and kinesthetic imagery have been identified as separate modalities, it is vital that this differentiation translates into imagery ability questionnaires so that conceptually meaningful data can be obtained. Consequently, the current study sought to develop and validate an imagery ability questionnaire, with IVI and kinesthetic imagery considered as separate modalities.

The second reason for reexamining the VMIQ relates to the precise conceptualization of external visual imagery. External visual imagery has been defined as either watching someone *else* perform an action (e.g., Ruby & Decety, 2001), or watching *oneself* perform an action from a third-person perspective (White & Hardy, 1995). Although this difference in definitions at first appears trivial, it has been suggested that self and other imagery may involve different cognitive processes (see Denis, Englekamp, & Mohr, 1991; Callow & Hardy, 2004) and neurological profiles (e.g., Farrer & Frith, 2002). Indeed, the relationship between external visual imagery and kinesthetic imagery is stronger when the imager imagines him- or herself from an external perspective than when he or she imagines someone else from an external

perspective (Callow & Hardy, 2004). With this in mind, it is surprising that the visual subscale of the VMIQ directs participants to create an image of someone *else*, as opposed to watching *oneself* performing. This perhaps limits the VMIQ because it fails to assess external self imagery, which is more commonly experimentally manipulated in comparison with external other imagery (e.g., Glisky et al., 1996). In the current study, external visual imagery was defined as third-person imagery of the *self*, specifically external self visual imagery (EVI).

The third reason for our agreement that the VMIQ should be reexamined relates to a lack of rigorous psychometric testing of this instrument. Within imagery research, psychometric testing of questionnaires is seen as a crucial part of assessing the integrity of particular measures (McKelvie, 1994). For example, the VMIQ has been shown to display acceptable temporal stability and convergent validity (Isaac et al., 1986). However, the factor structure of the VMIQ has only been assessed using exploratory factor analysis (e.g., Atienza, Balaguer, & Garcia-Merita, 1994; Campos & Perez, 1990), as opposed to more rigorous testing procedures using confirmatory factor analysis techniques. Confirmatory factor analysis (CFA) has been advocated as a superior method to test the underlying factor structure of an instrument because CFA utilizes a theory-driven approach, whereas exploratory factor analysis employs a data-driven approach (Biddle, Markland, Gilbourne, Chatzisarantis, & Sparkes, 2001). Therefore, CFA would seem a more acceptable way to test the factor structure of the VMIQ, allowing imagery researchers to be confident in factorial integrity of the questionnaire.

Consequently, the general purpose of the present research program was to create an appropriately modified version of the VMIQ that was psychometrically valid. To this end, the instructional set of the VMIQ was altered so as to be able to assess IVI and kinesthetic imagery as separate modalities, and EVI as third-person imagery of the self. The psychometric properties of this questionnaire were then tested. Thus, the present research comprised three studies. Study 1 examined the factorial validity of an amended version of the VMIQ (the VMIQ-2) using CFA techniques. In the second study, the aim was to further examine the factor structure of a revised VMIQ-2 using CFA. Finally, the aim of the third study was to assess the concurrent and construct validity of the VMIQ-2.

## Study 1

### Participants

An opportunistic sample of 351 British athletes ( $M$  age = 20.44,  $SD$  = 3.59 years,  $n$  = 189 males,  $n$  = 159 females,  $n$  = 3 sex not given) was recruited for the study. All gave their written consent to take part in the study. Athletes had an average of 7.61 years ( $SD$  = 3.86) of competing in their sport and were from a variety of team and individual sports. The level of competition ranged from recreational to international and/or professional or semi-professional (recreational  $n$  = 30, club  $n$  = 87, county  $n$  = 35, university  $n$  = 113, national  $n$  = 34, international and/or professional or semiprofessional  $n$  = 28, level not reported  $n$  = 24).

## Measures

**Vividness of Movement Imagery Questionnaire (VMIQ).** The purpose of the VMIQ is to assess the ability to visually and kinesthetically image a variety of movements, and comprises 24 items. When completing the VMIQ, participants are required to imagine each item twice: first by imagining watching somebody else perform the movement and second by imagining performing the movement themselves. Thus, there are 48 responses in total. The 24 items fall into six groups, with four items in each group. The groups are as follows: items relating to basic body movements (Items 1–4), items relating to basic movements with more precision (Items 5–8), items relating to movement with control but some unplanned risk (Items 9–12), items relating to movement controlling an object (Items 13–16), items relating to movements that cause imbalance and recovery (Items 17–20), and items relating to movements demanding control in aerial situations (Items 21–24). The test–retest reliability of the VMIQ has been demonstrated over a 3-week period with a group of physical education students,  $r = .76$  (Isaac et al., 1986). The VMIQ has also demonstrated adequate concurrent validity with the Vividness of Visual Imagery Questionnaire with novice, experienced, and international-level trampolinists. The correlations were 0.75, 0.45, and 0.65 respectively (Isaac et al., 1986).

### Adaptation of the VMIQ (VMIQ-2)

To provide an assessment of IVI, EVI, and kinesthetic imagery (KIN) ability, the instructional set of the VMIQ was adapted. The wording on the existing factors was changed to assess IVI, EVI, and KIN in line with current conceptualizations. Specifically, IVI was defined as first-person visual imagery, EVI as third-person imagery of the self, and KIN as imagery of the feel of the movement (e.g., Glisky et al., 1996; Hardy & Callow, 1999). Thus, the IVI factor asks a participant to imagine the items as if “you are looking out through your own eyes.” The EVI factor asks a participant to imagine the items as if “you are watching yourself performing the movement” from an external perspective. The KIN factor asks a participant to “imagine feeling yourself doing the movement.” The original 24 items were kept, with each item imaged in three ways (e.g., the item for jumping off a high wall was imaged using IVI, EVI, and KIN); thus, there were 72 responses in total. To measure the vividness of each image, the Likert scale from the original VMIQ, from 1 (*perfectly clear and vivid*) to 5 (*no image at all, you only know that you are “thinking” of the skill*), was used. Four experts in imagery and measurement examined the questionnaire for face validity and deemed it acceptable.

To facilitate accurate completion of the VMIQ-2, the layout of the questionnaire was changed. In the original VMIQ participants are asked to read the rating scale, image an item, and insert the relevant number into the blank area beside the item. Following discussion among the authors and based on reports from participants in previous studies using the VMIQ who reported difficulties with remembering the direction of the rating scale (low scores correspond to more vivid imagery), it was deemed easier for participants to circle the appropriate number for each item imaged. Therefore, beside each item on the VMIQ-2 all possible responses were listed, and participants were asked to circle the most appropriate response for each item that was imaged.

## Procedure

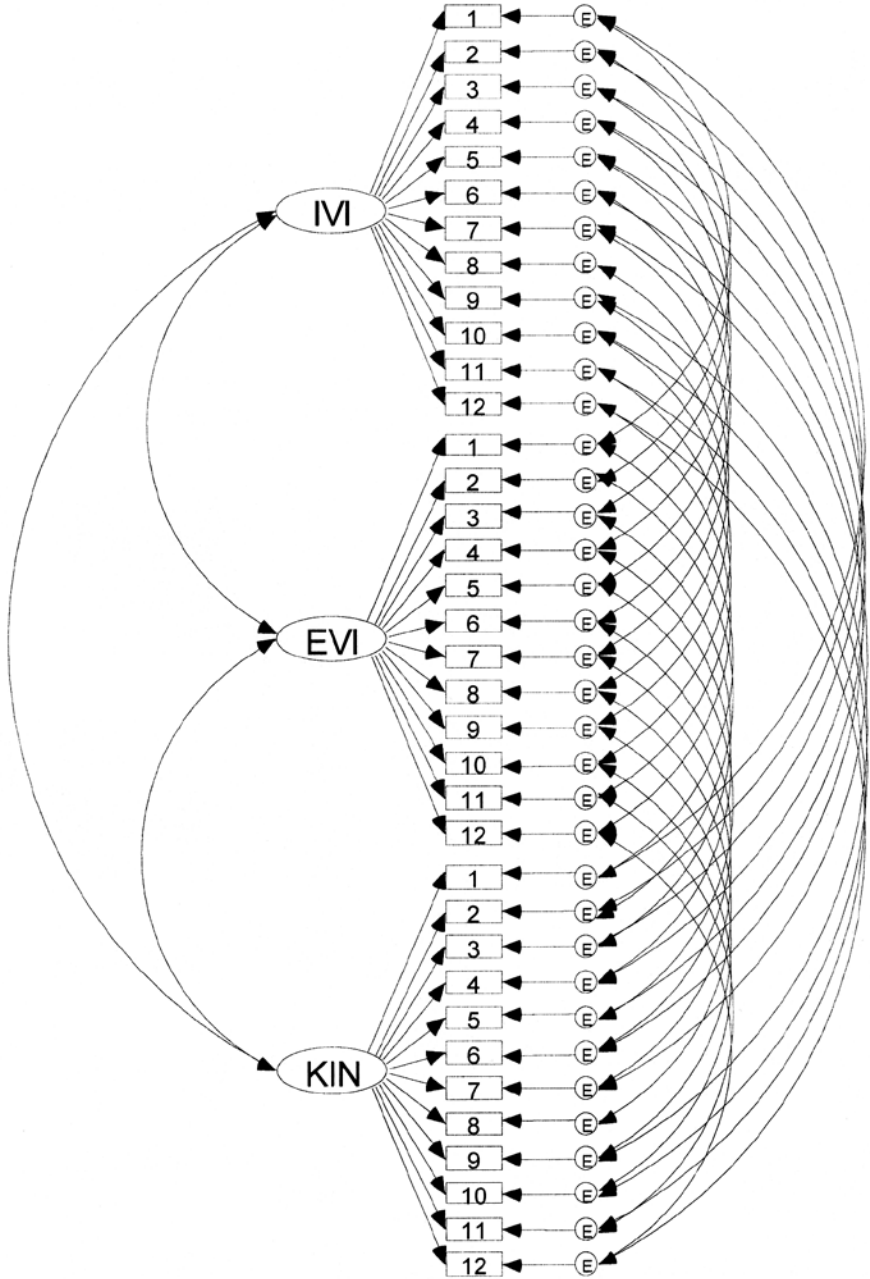
All participants completed the VMIQ-2 in a quiet environment, either in training sessions or at home, in groups of not more than 15. They were asked to complete all items on the questionnaire without conferring with others, and were assured of the confidentiality of their responses. The order in which participants were asked to complete the three factors on the questionnaire was counter-balanced to prevent ordering effects. The questionnaire was blocked by factor. That is, participants were asked to complete all 24 items using the first factor, then all items using the second factor, and finally all items using the third factor.

## Testing Procedure and Data Analysis

In the current study, the ideal testing procedure to examine the factorial structure of the 24-item VMIQ-2 would be to employ a multitrait multimethod (MTMM) approach to CFA using a correlated traits / correlated uniqueness (CTCU) model. This is because the 24-item VMIQ-2 uses the same item (e.g., kicking a stone) across each of the three factors (i.e., IVI, EVI, and KIN); thus, shared method variance exists for each item across each of the factors. A MTMM approach takes this measurement artifact and random error into account. Specifically, the approach allows for the true relationship among traits (factors) to be determined when shared method variance is present. The CTCU model does this by correlating the traits and inferring the method effects from the correlated uniqueness (of error) among the three responses that share the same method (i.e., there are 24 methods or items). See Figure 1 for an example 12-item CTCU model with three factors. Although four different MTMM models have been proposed, the CTCU model is preferred because it results in proper solutions for all sizes of matrices and samples tested (Kenny & Kashy, 1992; Marsh & Grayson, 1995). However, with the present questionnaire and a MTMM CTCU model, there are over 200 parameters to be measured, which results in the need for a sample size greater than 2,000 (cf. Tabachnick & Fidell, 2001). Therefore, an alternative sequential model testing strategy was adopted.

Based on recommendations in the literature (e.g., Biddle et al., 2001; Jöreskog, 1993), each factor was examined separately, using CFA. These three analyses were performed to identify any potential items for removal and retain only those items that were good indicators of their underlying latent variable (factor). Following item removal, a 12-item VMIQ-2 was generated. With a 12-item model, there are fewer parameters to be estimated, thus fewer participants are required. Consequently, a MTMM CTCU analysis was performed.

All analyses were conducted using LISREL 8.54 (Jöreskog & Sörbom, 2003) with the maximum likelihood estimation. To assess model fit for both the single factor analyses and the CTCU analysis, the following fit indices were employed: the Satorra–Bentler chi-square statistic (Satorra & Bentler, 1994), the root mean square error of the approximation (RMSEA; Steiger & Lind, 1980), the comparative fit index (CFI; Bentler, 1990), the non-normed fit index (NNFI; Tucker & Lewis, 1973), and the standardized root mean square residual (SRMR; Bentler, 1995). The Satorra–Bentler chi-square was used to correct for non-normality where the data showed departure from multivariate normality (indicated by large Mardia coefficients; Mardia, 1970).



**Figure 1** — Example CTCU model with 12 items per factor. Ellipses correspond to the three factors, IVI = internal visual imagery, EVI = external visual imagery, KIN = kinesthetic imagery. Numbers in rectangles correspond to example items. Circles containing an E are error variances.

The criteria set for a good model fit included a nonsignificant Satorra–Bentler chi-square ( $p > .05$ ). However, it has been recommended that the chi-square be used more subjectively as an index of fit rather than a test statistic, with large chi-square values relative to degrees of freedom indicating a poor fit, and small values indicating a good fit (Jöreskog & Sorbom, 1989). For assessing the fit indices, Hu and Bentler's (1999) relatively conservative criteria were also used (see Markland, 2007). Specifically, a RMSEA of less than .06 was taken to indicate a close fit, less than .08 a reasonable fit, and greater than 1.0 was taken as a poor fit. In addition, the probability that the RMSEA was larger than .06 was examined with the alpha level set at  $p > .05$ . Further, CFIs and NNFI of greater than .95, and SRMRs of less than .08 were all taken to indicate a good fit (cf. Hu & Bentler, 1999).

It has recently been argued (Hayduk & Glaser, 2000), that the only criterion to adequately test model fit is the chi-square test statistic, and that incremental fit indices should not be used at all (Barrett, 2007). However, this issue is the subject of much discussion within the literature (e.g., Barrett; Markland, 2007). Consequently, a combination of Hu and Bentler's (1999) criteria, with a recognition that these are not "golden rules" (see Marsh, Hau, & Wen, 2004), along with an examination of the chi-square/degrees-of-freedom ratio was employed to provide a balanced approach to testing model fit.

## Results

Data screening revealed no missing data, so the data from all 351 participants were analyzed.

**Single Factor Models.** The single factor analyses revealed poor fits for each of the three factors (see Table 1 for fit statistics). Item removal was based on two criteria. First, items were considered for removal if they displayed low factor loadings and/or highly positive or negative standardized residuals. Low factor loadings demonstrate items that are poor indicators of their underlying factor, and problem residuals can mean that the model is either under- or over-parameterized. Second, items not related to movement (e.g., standing) were also considered for removal. Both of these criteria were used to identify potential items for removal. Based on these criteria, two items from each of the six groups (e.g., items related to basic body movements, items demanding control in aerial situations) were removed, thus leaving 12 items in each factor. Items that were a "problem" in one factor were also a problem in the other factors. Consequently, the same items were deleted across each of the three factors. Reanalysis of the single-factor models revealed that the chi-square/degrees-of-freedom ratio was still high for each factor, with the RMSEA being problematic for two of the factors (see Table 2 for fit statistics). These poor fits are not surprising given that the single factor analyses fail to account for method effects. Given the issue of shared method variance, and the reduction in items from 24 to 12, the more appropriate CTCU analysis was conducted to test the three-factor structure of the 12-item VMIQ-2 (Table 3 shows the items that make up the 12-item VMIQ-2).

**CTCU Analysis.** The three-factor CTCU analysis performed on the 12-item questionnaire revealed an acceptable fit, Satorra–Bentler  $\chi^2(555) = 840.65$ ,  $p < .001$ ; RMSEA = .038,  $p = 1.00$ ; CFI = .98; SRMR = .044, NNFI = .97. Factor loadings



**Table 1 Fit Statistics for the Single Factor CFAs for the 24-Item Questionnaire**

Factor	S-B $\chi^2$	df	$\chi^2/df$	RMSEA	CFI	SRMR	NNFI
Internal visual imagery	748.55*	252	2.97	0.08*	0.97	0.06	0.96
External visual imagery	978.13*	252	3.88	0.09*	0.96	0.06	0.96
Kinesthetic imagery	920.87*	252	3.65	0.09*	0.95	0.06	0.95

Note. S-B  $\chi^2$  = Satorra–Bentler chi-square statistic, RMSEA = the root mean square error of the approximation, CFI = comparative fit index, SRMR = standardized root mean square residual, NNFI = the non-normed fit index.

\* $p < .001$ .

**Table 2 Fit Statistics for the 12-Item Single Factor Confirmatory Factor Analyses**

Factor	S-B $\chi^2$	df	$\chi^2/df$	RMSEA	CFI	SRMR	NNFI
Internal visual imagery	143.62*	54	2.65	0.07*	0.97	0.04	0.96
External visual imagery	175.58*	54	3.25	0.09*	0.97	0.05	0.96
Kinesthetic imagery	146.28*	54	2.71	0.09*	0.95	0.06	0.95

Note. S-B  $\chi^2$  = Satorra–Bentler chi-square statistic, RMSEA = the root mean square error of the approximation, CFI = comparative fit index, SRMR = standardized root mean square residual, NNFI = the non-normed fit index.

\* $p < .01$ .

ranged from .60 to .78, with the following interfactor correlations: IVI and EVI = .39, IVI and KIN = .63, EVI and KIN = .41. Although the scaled chi-square was still significant, the chi-square/degrees-of-freedom ratio was substantially reduced to 1.5. The other fit indices were in line with Hu and Bentler's (1999) recommendations.

Closer inspection of the correlated error variances revealed that although most had significant correlations, some of the correlations between error variances (8 of a total of 36) were not significant. As some of the correlations were nonsignificant, a second CTCU analysis was performed, with the eight nonsignificant correlations being fixed to zero (i.e., they were not allowed to correlate). Again, the analysis revealed an acceptable model fit, with similar fit statistics as in the previous analysis (see Table 4 for fit statistics; the model is labeled *CTCU-12a*). Inspection of the correlated errors revealed that two new error variances that had been significantly correlated in the earlier model were now no longer significant. Thus, a third CTCU analysis was run with the new nonsignificant correlations between error variances being fixed to zero (i.e., in total 10 nonsignificant error terms were fixed to zero). This third CTCU model (labeled *CTCU-12b*) revealed an acceptable fit, with similar fit statistics as in the previous two CTCU analyses (see Table 4 for fit statistics). All of the remaining correlated errors were significant.

**Table 3 The 12 Items of the VMIQ-2 (With Specific Reference to the EVI Factor)**

Item	Watching yourself performing the movement (External visual imagery)				
	Perfectly clear and vivid as normal vision	Clear and reasonably vivid	Moderately clear and vivid	Vague and dim	No image at all, you only know that you are thinking of the skill
1. Walking	1	2	3	4	5
2. Running	1	2	3	4	5
3. Kicking a stone	1	2	3	4	5
4. Bending to pick up a coin	1	2	3	4	5
5. Running up stairs	1	2	3	4	5
6. Jumping sideways	1	2	3	4	5
7. Throwing a stone into water	1	2	3	4	5
8. Kicking a ball in the air	1	2	3	4	5
9. Running downhill	1	2	3	4	5
10. Riding a bike	1	2	3	4	5
11. Swinging on a rope	1	2	3	4	5
12. Jumping off a high wall	1	2	3	4	5

**Table 4 Fit Statistics for the Correlated Traits / Correlated Uniqueness (CTCU) Models**

CTCU model	S-B $\chi^2$	df	$\chi^2/df$	RMSEA	CFI	SRMR	NNFI
12-item	840.65*	555	1.51	0.04 ( <i>ns</i> )	0.98	0.04	0.97
12a	848.08*	563	1.51	0.04 ( <i>ns</i> )	0.98	0.04	0.97
12b	856.24*	565	1.52	0.04 ( <i>ns</i> )	0.98	0.04	0.97

Note. S-B  $\chi^2$  = Satorra–Bentler chi-square statistic, RMSEA = the root mean square error of the approximation, CFI = comparative fit index, SRMR = standardized root mean square residual, NNFI = the non-normed fit index.

\* $p < .001$ .

To compare the model fit of the three 12-item CTCU models, Satorra and Bentler's (2001) scaled difference chi-square test was used. The test revealed no significant differences between the original 12-item CTCU model and models CTCU-12a and CTCU-12b. However, there was a significant difference between model CTCU-12a and CTCU-12b ( $p < .01$ ), with model CTCU-12a fitting significantly better than model CTCU-12b. The fact that no difference in fit was obtained between the original hypothesized 12-item model (all error terms correlating) and the two subsequently produced CTCU models (CTCU-12a and CTCU-12b) provides support for the model fit of the original 12-item model with all error terms correlated.

Although the CTCU analyses supported the three-factor structure of the VMIQ-2, it is worth noting that the correlation between the IVI and KIN factors was .63, indicating a significant relationship. Consequently, because of this correlation and the view that IVI and KIN can occur together in terms of motor imagery (e.g., Lotze & Halsband, 2006), the data were subjected to a reanalysis. The aim of this reanalysis was to examine whether, from a measurement perspective, having IVI and KIN as separate factors or motor imagery is more factorially valid. Specifically, two analyses were performed. The first was a two-factor CTCU analysis treating the IVI and KIN factors as separate. The second analysis simulated a one-factor model; specifically, IVI and KIN were simulated as one factor by fixing their correlation to 1.0. The analyses revealed the following fit statistics: two-factor CTCU, Satorra–Bentler  $\chi^2(239) = 416.35$ ,  $p < .001$ ; RMSEA = .05,  $p > .81$ ; CFI = .98; SRMR = .04; NNFI = .98; and simulated one-factor, Satorra–Bentler  $\chi^2(240) = 2,320.63$ ,  $p < .001$ ; RMSEA = .16,  $p < .001$ ; CFI = .92; SRMR = .10; NNFI = .90. A Satorra–Bentler (2001) scaled difference chi-square test revealed that the fit of the two-factor model was significantly better than the simulated one-factor model ( $p < .05$ ). Furthermore, the difference in CFI between the two models was greater than .01, with higher a CFI for the two-factor model, indicating that the two models were not invariant (see Cheung & Rensvold, 2002).

## Discussion

The aim of Study 1 was to examine the factorial validity of an adapted version of the VMIQ (VMIQ-2). The single factor CFAs revealed poor fits to the data; however, following item deletion, the three-factor CTCU analysis revealed an acceptable

model fit, especially given the number of parameters in the model. When the three different 12-item models were tested, there was no difference in fit between the original 12-item model (all error terms correlated) and Models 12a (eight uncorrelated error terms) and 12b (10 uncorrelated error terms), thus indicating all models were of an equally acceptable fit. However, because the original model is based on theory as opposed to being computed following post hoc model adjustment, the original model is the model of choice (cf. Biddle et al., 2001).

The support provided for the three-factor structure of the VMIQ-2 by the CTCU analysis suggests that from a measurement perspective at least, IVI and KIN should be treated as separate modalities. This was further confirmed by the subsequent reanalysis comparing IVI and KIN as separate modalities in a two-factor model, against the simulated one-factor model (where IVI and KIN were considered as one modality). In this analysis, the two-factor model displayed a significantly better fit than the simulated one-factor model, indicating that despite their significant correlation IVI and KIN should be considered separately (cf. Glisky et al., 1996).

With the factor structure of the VMIQ-2 initially established, the second study sought to further examine the factorial validity of the VMIQ-2 with a different sample.

## Study 2

### Participants

An opportunistic sample of 355 British athletes ( $M$  age = 20.05,  $SD$  = 3.24 years,  $n$  = 235 males,  $n$  = 119 females,  $n$  = 1 sex not reported) was recruited for the study. All gave their written consent to take part. Athletes had an average of 7.32 years ( $SD$  = 4.08) of competing in their sport, and were from a variety of team and individual sports. The level of competition ranged from recreational to international and/or professional or semi-professional (recreational  $n$  = 48, club  $n$  = 51, county  $n$  = 10, university  $n$  = 103, national  $n$  = 47, international and/or professional or semiprofessional  $n$  = 27, level not reported  $n$  = 69).

### Measures

The 12-item VMIQ-2 from Study 1 was administered.

### Procedure

As in Study 1, all participants completed the VMIQ-2 in a quiet environment, either in training or at home, and in groups of not more than 15. Participants were asked to refrain from conferring with others, and the confidentiality of their responses was assured. The order in which participants were asked to complete the three factors on the questionnaire was randomized to prevent ordering effects.

### Data Analysis

Confirmatory factor analysis using the CTCU approach was employed. Specifically, in line with Study 1, a three-factor CTCU analysis with all error terms correlated was performed. In addition, the same criteria for assessing model fit were used.

## Results

Data screening revealed that 19 participants had missing data points (2% of the total number of data points). When missing data points are 5% or less than the total number of data points, exclusion of data from participants with missing data points is an appropriate strategy (Tabachnick & Fidell, 2001). Consequently, the data from the 19 participants were removed, with the analysis performed on data from 336 participants.

The CTCU analysis revealed the following fit statistics: Satorra–Bentler  $\chi^2(555) = 1,242.76, p < .001$ ; RMSEA = .06,  $p < .001$ ; CFI = .98; SRMR = .06, NNFI = .97. Factor loadings ranged from 0.64 to 0.82, with the following interfactor correlations: IVI and EVI = .51, IVI and KIN = .62, EVI and KIN = .43. Although the chi-square was significant, and the chi-square/degrees-of-freedom ratio was rather high, the rest of the fit statistics were within recommended limits (cf. Hu & Bentler, 1999).

To provide continuity with Study 1, a comparison of a two-factor CTCU analysis with IVI and KIN as separate factors against a simulated one-factor model was performed. The analyses revealed the following fit statistics for the two-factor CTCU model: Satorra–Bentler  $\chi^2(239) = 638.07, p < .001$ ; RMSEA = .07,  $p > .001$ ; CFI = .97; SRMR = .05; NNFI = .97. However, the simulated one-factor model would not converge. Therefore, to be able to compare whether IVI and KIN should be treated as separate factors or one factor, a “true” one-factor model was run, where all 24 items (12 IVI and 12 KIN) loaded onto one factor. This model revealed the following fit statistics: Satorra–Bentler  $\chi^2(240) = 3,150.36, p < .001$ ; RMSEA = .19,  $p < .001$ ; CFI = .90; SRMR = .11; NNFI = .89. In comparing the two-factor model against the one-factor model, the two-factor model resulted in the lowest consistent Akaike information criterion (1,055.17 vs. 3,560.62). This suggests, based on parsimony, that the two-factor model may be a better model (cf. Byrne, 1998). Further to this, the CFIs of the two models were compared, as in Study 1. Consistent with the first study, the difference in CFI was greater than .01, with the two-factor model again reporting a higher CFI. Taking these two results together provides additional support for the delineation of IVI and KIN as separate modalities.

## Discussion

In Study 2, the factorial validity of the VMIQ-2 was further explored. The results of the three-factor CTCU analysis revealed a satisfactory model fit, although it must be noted that the chi-square test was significant and larger than in the previous study. However, the fit indices were acceptable and were similar to the results of the first study. Comparing whether IVI and KIN should be treated as separate or as the same factor revealed findings similar to those in Study 1. Specifically the two-factor model was the most parsimonious, with a CFI that was greater than the one-factor model by more than .01.

Despite the significant chi-square and relatively high chi-square/degrees-of-freedom ratio in Study 2, and taking the results from Studies 1 and 2 together, there appears to be initial support for the validity of the three-factor structure of the VMIQ-2. This suggests that the VMIQ-2 has the potential to be a useful measure of

movement imagery ability. Study 1 had a fairly low chi-square/degrees-of-freedom ratio, and for both studies the fit indices met or exceeded proposed criteria (Hu & Bentler, 1999). Whereas these criteria should not be viewed as golden rules (Marsh et al., 2004), it is encouraging that at the very least they were met or surpassed in both studies. With support provided for the factorial validity of the VMIQ-2, the third and final study assessed the concurrent and construct validity of this measure.

### Study 3

The aim of Study 3 was to assess the concurrent and construct validity of the VMIQ-2. Concurrent validity relates to whether the VMIQ-2 correlates with already validated imagery ability measurement tools (cf. Thomas, Nelson, & Silverman, 2005). As with many studies, it is difficult to test this form of validity because there is often no gold standard criterion. Nevertheless, in the current study, the Movement Imagery Questionnaire-Revised (MIQ-R; Hall & Martin, 1997) seemed a suitable criterion choice because its internal consistency and reliability have been demonstrated. However, it is important to note that there are limitations associated with using the MIQ-R. First, the MIQ-R does not measure vividness specifically; rather, it is a measure of the ease/difficulty to create an image. Second, there is no distinction made between visual imagery perspectives (i.e., IVI and EVI). Third, the factorial validity of the MIQ-R has not been assessed using CFA. Nevertheless, the MIQ-R does at least make a distinction between visual and kinesthetic imagery; thus, the concurrent validity of the VMIQ-2 factors can be partially assessed. A further strength of using the MIQ-R to assess concurrent validity is that the VMIQ-2 and MIQ-R may overlap in the processes they reflect. Indeed, it was suggested in the introduction that vividness may reflect the processes of formation, transformation, and maintenance, and it is also likely that the ease of image creation assessed by the MIQ-R requires the same processes.<sup>1</sup>

Construct validity can be assessed using a variety of methods (cf. Cronbach & Meehl, 1955; Thomas et al., 2005). One such method is to find expected differences between distinct groups. In relation to imagery ability, research has demonstrated significant differences in reported imagery ability between athletes of varying skill levels. For example, elite athletes have reported more vivid imagery than nonelite athletes (Oishi & Maeshima, 2004). In addition, research involving the original VMIQ has demonstrated significant differences between varsity and nonathletes (Eton et al., 1998), and between elite athletes and nonelite matched controls (Isaac & Marks, 1994). In both cases, higher level athletes reported greater vividness. Evidence for the construct validity of the VMIQ-2 could therefore be obtained by demonstrating differences in imagery ability scores in elite and nonelite athletes.

Thus in the current study it was expected that concurrent validity would be supported by significant correlations being obtained between requisite factors of the VMIQ-2 and the MIQ-R. Specifically, it was expected that the visual imagery factor of the MIQ-R would correlate significantly with the IVI factor from the VMIQ-2 and also the EVI factor. The kinesthetic imagery factors from the two questionnaires were expected to correlate significantly. To support construct validity, it was expected that elite athletes would report significantly greater imagery ability than nonelite athletes.

## Participants

**Concurrent Validity.** An opportunistic sample of 71 athletes ( $M$  age = 21.72,  $SD$  = 3.39,  $n$  = 55 males,  $n$  = 16 females) was voluntarily recruited for the study. All gave their written consent to take part. Athletes had an average of 8.26 ( $SD$  = 4.35) years of competing in their sport, and were from a variety of team and individual sports. The level of competition ranged from recreational to international (recreational  $n$  = 16, club  $n$  = 8, university  $n$  = 35, national  $n$  = 8, international  $n$  = 2, level not reported  $n$  = 2).

**Construct Validity.** To test the construct validity of the VMIQ-2, the samples from all three studies were combined, making a total of 777 participants. From this sample, 146 high-level and 240 low-level athletes were then identified. In line with previous research (e.g., Isaac & Marks, 1994; Eton et al., 1998), the high-level athletes were defined as those who participated in their sport at a national level and above, and low-level athletes were those who participated in their sport at a recreational and club level. To ensure that each sport was represented equally in each group, participants were matched for sport type across the two groups. Where sports were not matched, the respective data were deleted from the sample. This resulted in a sample of 198 sport-matched participants, 99 per group.

## Measures

**Vividness of Movement Imagery Questionnaire-2 (VMIQ-2).** The 12-item VMIQ-2 from the first study was used as the predictor.

**Movement Imagery Questionnaire-Revised (MIQ-R).** The MIQ-R served as the criterion variable. The MIQ-R comprises eight items that measure both visual and kinesthetic imagery ability. Participants are asked to assume a starting position, and then perform a movement, such as raising their right knee as high as possible, and then lowering their leg back to the starting position. They are then asked to either visually or kinesthetically image themselves performing the movement and are asked to rate the ease or difficulty with which this is done. The factorial validity of the original Movement Imagery Questionnaire (MIQ) has been supported by Atienza et al. (1994). The reliability of the MIQ has also been demonstrated as acceptable, with test-retest coefficients of .83 for a 1-week interval being reported (Hall, Pongrac, & Buckolz, 1985). Significant correlations between the MIQ and MIQ-R have been obtained, for both the visual and kinesthetic subscales, suggesting the MIQ-R to be a suitable revision of the MIQ.

## Procedure

Participants completed the questionnaires in a quiet environment in groups of not more than five. Confidentiality of responses was assured and participants were asked not to confer with anyone else. The order in which groups of participants received the MIQ-R and VMIQ-2 was counterbalanced. To facilitate accurate completion

of the MIQ-R, participants were guided through its completion. Specifically, the primary author read out each movement to be completed by the participants, and watched each participant to make sure that all actions were performed fully (see Short & Short, 2002).

## Analysis

**Concurrent Validity.** Pearson's product-moment correlations were calculated to assess the strength of relationships between the scores on each factor of the VMIQ-2 with corresponding scores on the factors of the MIQ-R. For example, the kinesthetic imagery factor on the VMIQ-2 was correlated with the kinesthetic factor of the MIQ-R, and each visual imagery factor of the VMIQ-2 was correlated with the visual imagery factor of the MIQ-R. Based on their reliability coefficients, the strength of the correlations between the requisite factors was adjusted so as to take any possible measurement error into account (cf. Biddle et al., 2001). Further, as multiple correlations were conducted, an adjustment was made to the critical  $r$  to reduce the likelihood of a Type I error occurring (Schutz & Gessaroli, 1993).

**Construct Validity.** To compare differences between the high- and low-level athletes, independent samples  $t$  tests were performed on each of the three factors. To control for a Type I error, the alpha level for each  $t$  test was adjusted to .017 using a Bonferroni correction.

## Results: Concurrent Validity

The data were analyzed for normality; however, this revealed significantly skewed data, with eight outliers. These data were removed and subsequent checks were within accepted limits. The correlation analyses were therefore performed on the remaining 63 participants. To control for Type I error when performing multiple correlations, an adjustment needs to be made to the critical  $r$ . This adjustment is based on the number of tests to be performed and the degrees of freedom. Consequently, in the current study with three tests and 61 degrees of freedom, the critical  $r$  for a significant correlation at  $p < .05$  was  $r = .308$  (see Shavelson, 1988). Reliability analysis revealed the following alpha coefficients for the VMIQ-2: IVI = .95, EVI = .95, KIN = .93. For the MIQ-R, the alpha coefficients were .85 for visual imagery and .79 for kinesthetic imagery.

The results revealed that both the IVI and EVI factors were significantly correlated with the visual factor of the MIQ-R, IVI and visual imagery,  $r = -.342$  ( $p < .05$ ), EVI and visual imagery  $r = -.647$  ( $p < .01$ ). The KIN factors were both significantly correlated, KIN and kinesthetic imagery,  $r = -.736$  ( $p < .01$ ). The negative correlations are due to the two measures being scored in opposite directions.

Using Meng and colleagues' (1992) adjusted  $z$  score equation, the strength of the correlations between IVI (VMIQ-2) and visual imagery (MIQ-R), and EVI (VMIQ-2) and visual imagery (MIQ-R) were compared. The analysis revealed a significant difference between the two correlations ( $z = 2.22$ ,  $p < .03$ ).



## Results: Construct Validity

The assumption of homogeneity of variance was met for the analyses performed on the EVI factor, but not on the IVI and KIN factors. Consequently, equal variance not assumed *t* tests were used to analyze the data from the IVI and KIN factors. The *t* tests revealed significant differences between the high- and low-level athletes for each variable: for IVI,  $t(181.66) = -2.56, p < .01, d = .36$ ; for EVI,  $t(196) = -2.55, p < .01, d = .36$ ; and for KIN,  $t(186.49) = -2.87, p < .005, d = .40$ . Inspection of the cell means revealed that in all cases the high-level athletes had greater imagery ability indicated by lower mean scores (see Table 5 for descriptive statistics).

## Discussion

The aim of Study 3 was to examine the concurrent and construct validity of the VMIQ-2. Taken together, the results of Study 3 provide initial support for the concurrent and construct validity of the VMIQ-2.

In general, the concurrent validity analysis revealed the expected results. Specifically, the kinesthetic imagery factors of the VMIQ-2 and MIQ-R were correlated, as were the EVI and visual imagery factors, and IVI and visual imagery factors. Of note was that the correlation between EVI and visual imagery was significantly greater than the IVI and visual imagery correlation. Whereas it might initially be expected that the correlations between the two visual imagery perspectives from the VMIQ-2 and the visual imagery scale from the MIQ-R would be similar (because the MIQ-R makes no distinction about which visual perspective should be used to image from), examination of the items contained in the MIQ-R suggests that a stronger relationship should exist between EVI (VMIQ-2) and visual imagery than between IVI (VMIQ-2) and visual imagery. To expand, the items on the MIQ-R require participants to perform movements that depend heavily on form for their successful execution (see Callow & Hardy, 2004), and previous research (e.g., Hardy & Callow, 1999; White & Hardy, 1995) has demonstrated that EVI is superior to IVI for the acquisition and performance of tasks where form is important. Hardy (1997) suggests that these effects are caused by imagery providing additional information to the performer that would otherwise be unavailable. In particular, in tasks where form is important, EVI provides additional information about the shape of the body as it moves. Consequently, the items on the MIQ-R might have led participants to adopt an external visual perspective or to produce more vivid EVI, leading to a stronger correlation between EVI (VMIQ-2) and visual imagery. The significant differences in the correlations should, therefore, be seen as a strength of the VMIQ-2.

**Table 5 Means (SD) for Factor Scores on the 12-item VMIQ-2**

Group	Internal visual imagery	External visual imagery	Kinesthetic imagery
High level	23.48 (8.47)	26.53 (9.62)	23.95 (8.95)
Low level	27.14 (11.31)	30.22 (10.76)	28.10 (11.26)

The data from the construct validity analyses were also encouraging. In all three analyses (IVI, EVI, KIN) the high-level athletes reported significantly more vivid imagery than did the low-level athletes. These results support previous research (e.g., Isaac & Marks, 1994; Oishi & Maeshima, 2004) that has demonstrated greater imagery ability in higher level athletes. Because imagery ability is a skill that can be improved through practice (Rodgers, Hall & Buckolz, 1991), the above result is not surprising. High-level athletes engage in more deliberate imagery practice than low-level athletes (Cumming & Hall, 2002), so greater imagery ability would be expected. Of note was that high- and low-level athletes differed in their kinesthetic imagery ability. Kinesthetic imagery may be particularly important for high-level performers because it may help them gain a detailed feel for movements (Hardy & Callow, 1999).

## General Discussion

The general purpose of this program of research was to amend the VMIQ by taking into account specific imagery modality and perspective conceptualizations (cf. Hardy & Callow, 1999; White & Hardy, 1995), to provide a more comprehensive and psychometrically acceptable assessment of movement imagery ability.

Taken together, the results of the three studies provide preliminary support for the VMIQ-2 as an improved revision of the original VMIQ that displays factorial, concurrent, and construct validity. Studies 1 and 2 also provided support for the delineation of IVI and KIN into separate modalities. These results indicate that, from a measurement perspective at least, imagery modalities and visual perspectives should be treated separately, and conceptually should not be confused. These results corroborate findings from both behavioral (e.g., Glisky et al., 1996) and neuroscientific (e.g., Fourkas et al., 2006) research, which demonstrates the delineation of internal visual and kinesthetic imagery.

Several potential implications, and one limitation, can be identified from the present research. With reference to the implications, to provide further information concerning individual imagery experiences, it has been recommended that a combination of measures, both objective (e.g., autonomic nervous system recordings) and subjective (e.g., questionnaires) are used (Guillot & Collet, 2005). Because the VMIQ-2 appears to be a valid measure of movement imagery ability, its use in combination with other imagery tests may allow for more complete assessments of imagery ability to be made. A second implication is that the use of the VMIQ-2 may aid in the precision of brain functioning research in relation to perspectives and modality. Indeed, Ruby and Decety (2001) recently demonstrated both common and unique neural areas associated with first- and third-person (of someone else) imagery. However, modality (i.e., IVI or KIN) was not defined in first-person imagery and the participant was not the agent of the image in the external perspective. In addition, a distinction between first-person visual imagery and kinesthetic imagery has been made only in some studies (e.g., Fourkas et al., 2006). Because the VMIQ-2 requires the participant to be the agent of the image, administering the VMIQ-2 could allow for a check of the participant's imagery ability in the different modalities and perspectives, and may provide the relevant delineation, which may lead to more precise assessment of brain function during imagery. Thus, in certain situations, EVI of self rather someone else should be employed.

Within the sport setting, the VMIQ-2 has the potential to be of use to sport psychologists and coaches to use with athletes. Because imagery ability moderates the effectiveness of interventions (e.g., Isaac, 1992), using the VMIQ-2 could provide a comprehensive assessment of an athlete's imagery ability, prior to undertaking an imagery intervention. Furthermore, as task characteristics moderate the efficacy of imagery perspectives on performance (Hardy & Callow, 1999; White & Hardy, 1995), completion of the VMIQ-2 would provide a coach or practitioner with information about an athlete's ability to image movements using different perspectives. This information would be particularly useful for implementing the most appropriate intervention for the athlete and the type of sport that is played. Finally, reducing the number of items in the VMIQ-2 and, therefore, the time required for its completion are noteworthy. Specifically, athletes are known to dislike lengthy paperwork (see Beckmann & Kellmann, 2003), so the shortened length of the VMIQ-2 may result in athletes being more willing to complete the questionnaire.

A limitation of the present research was that a direct comparison between the VMIQ-2 and the original VMIQ was not made. A systematic examination of this comparison along with an exploration of predictive validity (e.g., does the three-factor 12-item VMIQ-2 predict more variance in performance than the two-factor original VMIQ?) would be a worthy avenue for future research. Indeed, previous research (Gregg, Hall, & Nesterhoff, 2005) has demonstrated a moderating effect of imagery ability on the imagery use/performance relationship. Additionally, high imagers, as measured by the original VMIQ, have been shown to display greater performance improvements following imagery-training programs than low imagers (Isaac, 1992). Replication of these findings using the VMIQ-2 would support the validity of this measure.<sup>2</sup>

To conclude, the current study provided an amended version of the VMIQ (VMIQ-2) based on contemporary modality and perspective conceptualization that had its factor structure assessed using confirmatory factor analytic techniques and construct validity tested. Preliminary support for the factor structure, concurrent validity, and construct validity was obtained, indicating that the VMIQ-2 appears to be a useful and psychometrically acceptable measure of movement imagery ability.

## Notes

1. We would like to thank an anonymous reviewer for this suggestion.
2. The Vividness of Movement Imagery Questionnaire-2 can be obtained by contacting the first author.

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