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Abstract

Mental imagery may occur in any sensory modality, although visual imagery has been most studied. A sensitive measure of the vividness of imagery across a range of modalities is needed: the shorter version of Bett's QMI (Sheehan, 1967) uses outdated items and has an unreliable factor structure. We report the development and initial validation of the Plymouth Sensory Imagery Questionnaire (Psi-Q) comprising items for each of the following modalities: Vision, Sound, Smell, Taste, Touch, Bodily Sensation and Emotional Feeling. An Exploratory Factor Analysis on a 35-item form indicated that these modalities formed separate factors, rather than a single imagery factor, and this was replicated by confirmatory factor analysis. The Psi-Q was validated against the Spontaneous Use of Imagery Scale (Reisberg, Pearson & Kosslyn, 2003) and Marks' (1995) Vividness of Visual Imagery Questionnaire-2. A short 21-item form comprising the best three items from the seven factors correlated with the total score and subscales of the full form, and with the VVIQ-2. Inspection of the data shows that while visual and sound imagery is most often rated as vivid, individuals who rate one modality as strong and the other as weak are not uncommon. Findings are interpreted within a working memory framework and point to the need for further research to identify the specific cognitive processes underlying the vividness of imagery across sensory modalities.

222 words

Assessing Vividness of Mental Imagery: The Plymouth Sensory Imagery Questionnaire

Mental imagery is often described as ‘seeing with the mind's eye’, ‘hearing with the mind's ear’, and so on (Kosslyn, Ganis, & Thompson, 2001; p. 635). Although visual imagery has been most intensively investigated, imagery can occur in any of the sensory modalities. Imagery allows us to ‘mentally time travel’ by recreating the past and simulating the future (Moulton & Kosslyn, 2009; Schacter, Addis, & Buckner, 2007), and plays a key role in our understanding of cognitive function. Imagery has been ascribed a functional role in motivation (Kavanagh, Andrade, & May, 2005), problem solving (Kozhevnikov, Motes, & Hegarty, 2007; Schwartz & Black, 1996), and the maintenance and treatment of clinical disorders (Hackmann, Bennett-Levy, & Holmes, 2011; Holmes & Mathews, 2010).

Since Galton (1883), vividness has been identified as a critical measure of imagery experience and intensity. The study of the subjective experience of imagery has been controversial, with justifiable concerns in relation to introspection (e.g., Baddeley & Andrade, 2000; Kosslyn, et al., 2001; Pearson, Rademaker, & Tong, 2011; Pylyshyn, 2003), but there is evidence that participants’ reports of image vividness respond in predictable, and sometimes counter-intuitive, ways to experimental manipulations (Andrade, Kavanagh, & Baddeley, 1997; Baddeley & Andrade, 2000). In support of arguments that imagery plays a functional role in human behavior and well-being, vividness of imagery has been associated with motivation strength (Kavanagh, May, & Andrade, 2009), personality traits (Morris & Gale, 1974), motor performance (Callow, Roberts, & Fawkes, 2006), mood (Morina, Deeprose, Pusowski, Schmid, & Holmes, 2011), and physiological response (Lang, 1979).

Image vividness depends on the sensory and affective qualities of the concept or stimulus being imaged, availability and capacity of cognitive processes, and individual differences (Bywaters, Andrade, & Turpin, 2004). Baddeley and Andrade's model of imagery explains the cognitive processes by which sensory information is incorporated into an image (Baddeley & Andrade, 2000). In a series of experiments, they found that concurrent tasks designed to load the phonological loop or visuospatial sketchpad of working memory reduced the vividness of imagery in the same modality, thus visual imagery was less vivid while tapping a pattern on a keypad than while counting aloud, whereas the converse was true for auditory imagery. There were also general effects on image vividness of performing a secondary task compared with imagery-alone conditions. Based on these findings, Baddeley and Andrade proposed a working memory account of image vividness in which vividness is determined by the extent to which people are able to temporarily store and manipulate sensory detail in working memory. According to their model, vividness will be determined by stored knowledge (e.g., Pearson & Hollings, 2013), available perceptual information, capacity of modality-specific short-term memory systems, executive processes involved in retrieval and manipulation of information, and the complexity of the stimulus being imaged, as images of dynamic scenes have been found to be less vivid than images of static scenes when imagery time is constrained, (Baddeley & Andrade, 2000). Although the processes of retrieval, storage and manipulation work in concert to generate, maintain and transform images (Baddeley & Andrade, 2000; Roberts, Callow, Hardy, Markland, & Bringer, 2008), their separate contributions can be distinguished through experimental

(Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990) and survey methods (Dean & Morris, 2003).

This paper tests the hypothesis that vividness of imagery depends on, and differs with, sensory modality. Baddeley and Andrade compared visual and auditory imagery because the cognitive processes involved in temporarily storing and manipulating information in those sensory domains are well specified (Baddeley & Andrade, 2000), but the broader field of situated or embodied cognition assumes that activation of concepts, including conscious imagery, is associated with activation of sensory, motor, and emotional content intrinsic to those concepts (Barsalou, 1999, 2008). Consistent with this position is evidence for substantial overlap in the patterns of neural activation during imagery and actual perception (Ganis, Thompson, & Kosslyn, 2004; McNorgan, 2012). Furthermore, in support of the specific hypothesis that image vividness depends on reactivation of sensory information, there is tentative neuroimaging evidence that self-report ratings of vividness correlate with activation of the same sensory-specific cortices as perception (Cui, Jeter, Yang, Montague, & Eagleman, 2007; Herholz, Halpern, & Zatorre, 2012; Olivetti Belardinelli et al., 2009), though these studies were under-powered for the critical correlational analyses. Self-report ratings of imagery vividness also predict the perceptual consequences of that imagery on a binocular rivalry task (Pearson, et al., 2011), providing further evidence that individuals can reliably evaluate the vividness of imagery, and that vividness potentially reflects properties that influence perceptual and cognitive performance.

There are several self-report measures of imagery vividness. Of these, the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) and revised version (VVIQ-2; Marks, 1995) are most commonly used but, as noted earlier, imagery can occur in any of the sensory modalities. Although visual imagery is the most frequently studied form of imagery, measures have been developed to address other modalities. In sports psychology, the Movement Imagery Questionnaire-Revised (MIQ-R; Hall & Martin, 1997) and the Vividness of Movement Imagery Questionnaire (VMIQ; Isaac, Marks & Russell, 1986; VMIQ-2; Roberts et al., 2008) include items on kinaesthetic imagery of a range of motor tasks, alongside items on different forms of visual imagery of these activities. A number of measures exist to assess imagery in other modalities, such as the Clarity of Auditory Imagery Scale (CAIS; Willander & Baraldi, 2010), and the Vividness of Olfactory Imagery Questionnaire (VOIQ; Gilbert, Crouch & Kemp, 1998)

The focus of imagery scales upon single modalities limits their usefulness in research that investigates imagery across sensory modalities. A multi-sensory scale would be useful in several domains. In the clinical domain, it would facilitate the study of how individual differences in imagery contribute to differences in mood and responses to stressors. Disturbances in imagery across a range of sensory modalities have been identified, for example in social phobia individuals may experience distorted auditory imagery of how they imagine their voice comes across to others (Hirsch & Clark, 2007; Holmes, Arntz, & Smucker, 2007). Imagery for feelings and emotions, which is omitted from most vividness of imagery scales, has been associated with health anxiety, with clients detailing examples of imagery such as ‘what it would be like to have AIDS…feeling hopeless and desperate’ (Muse, McManus, Hackmann, & Williams, 2010; p. 795). In addition to visual imagery in post-traumatic stress disorder, hotspots in trauma memories may also include the sound of screaming or the feeling of a knife against one’s throat (Holmes, Grey, & Young, 2005). Detailed multi-sensorial imagery of “flash-forwards” to suicide has been described in bipolar depression (Hales, Deeprose, Goodwin, & Holmes, 2011) and unipolar depression (Holmes, Crane, Fennell, & Williams, 2007). In addiction, alcohol-dependent clients report imagery of tasting and swallowing alcohol as well as visual images of drinking (Kavanagh et al, 2009; Statham, Connor, Kavanagh, et al., 2011) and substance craving generally is associated with vivid and frequent olfactory and taste imagery (May, Andrade, Panabokke, & Kavanagh, 2004). Studies of individual differences in susceptibility to craving or anxiety disorders would benefit from a measure of vividness of imagery across sensory domains.

A multi-sensory scale could also identify strengths and weaknesses in imagery, helping tailor movement learning programmes to individuals. Kinaesthetic imagery is a developing therapy in neurological rehabilitation (see review by Braun, Beurskens, Borm, Schack, & Wade, 2006). Kinaesthetic and somatic imagery are recognised as playing an important part in movement learning (Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009; Schuster, Hilfiker, Amft, et al., 2011; Yaguez, Nagel, Hoffman, Wist & Homberg, 1998), and are a focus of research in dance and choreography (Jackson, 2005; Krasnow, Chatfield, Barr, Jensen, & Dufek, 1997; Reason & Reynolds, 2010; May, Calvo-Merino, deLahunta, et al., 2011).

Not only would a multisensory measure of image vividness contribute to the understanding of individual differences in mood states, psychological disorders, mental rehearsal and motivation, it is also essential for furthering our understanding of the basic neural and cognitive processes underpinning imagery. The studies cited above, showing that image vividness is associated with activation in sensory cortices (Cui, et al., 2007; Herholz, et al., 2012), used modality-specific measures of vividness, that is, the VVIQ and the Bucknell Auditory Imagery Scale (Zatorre, Halpern, & Bouffard, 2010). To demonstrate that sensory activation is specific to the modality of imagery, and that vividness depends upon that sensory activation, researchers need to compare areas of brain activation and vividness of imagery across a range of imagery modalities (Olivetti Belardinelli et al., 2009). A multisensory measure of vividness would help identify the modality-general and modality-specific contributions to imagery and image vividness (Daselaar, Porat, Huijbers, & Pennartz, 2010; McNorgan, 2012).

A multisensory measures does exist: Bett's Questionnaire upon Mental Imagery (QMI; Betts, 1909) was an early attempt to extend Galton's work on imagery. It assesses vividness of imagery across seven sensory modalities: visual, auditory, cutaneous (i.e., touch), kinaesthetic (i.e., movement), gustatory (i.e., taste), olfactory (i.e., smell) and organic (i.e., feeling or emotion). However, it consists of 150 items and is often considered prohibitively long. A shortened form consisting of a subset of 35 items has been developed (Sheehan, 1967) but the factor structure has not been reliably confirmed. Richardson (1994, pp. 17-18) suggests that that the shortened QMI typically measures a single factor of general imagery vividness, although noting that secondary modality-specific factors have occasionally been found, and McAvinue and Robertson (2006-7, p.193) stated that 'factor analyses of the questionnaire items have tended to reveal a large unitary factor representing general vividness of imagery and/or modality specific factors'. Wagman and Stewart (1974) found a five factor structure with single or combined modalities, while Campos and Pérez-Fabello (2005) found eight factors in a Spanish translation, six matching modalities from the English original. White, Ashton and Law (1974) argued for a single imagery factor, with a large first factor representing demand characteristics and a smaller second factor representing relationships between modalities, and later showed that modality specific factors only emerged when the items were presented blocked in modality specific sets (White, Ashton & Law, 1978). Evidence for a single factor underpinning individual differences in image vividness across sensory modalities is problematic for approaches that assume a contribution of modality-specific processing to image vividness (Baddeley & Andrade, 2000; Barsalou, 2008), and contradicts neuroimaging evidence relating vividness to activation in sensory cortices (Cui et al., 2007; Herholz et al., 2012; Olivetti Belardinelli et al., 2009). A reliable measure of image vividness across modalities is needed to address this issue.

It is possible that the uncertain factor structure of the QMI results from problems in the composition of the scale. The rating scale is non-intuitive, with vividness being scored from 1 'perfectly clear and vivid' to 7 'no image present at all'. The word cues are lengthy, e.g., "Seeing, for a relative or friend, the precise carriage, length of step, etc., in walking", and language is often outdated, e.g., 'Seeing the colour and shine of silverware', hearing 'the sound of escaping steam'.

This paper reports the Plymouth Sensory Imagery Questionnaire (Psi-Q), which overcomes the limitations of the QMI discussed above to provide a measure of vividness of imagery across a range of sensory modalities – visual, auditory, olfactory, taste, touch, bodily sensation, and emotional feeling - that is suitable for use across the breadth of research domains where imagery is a variable of interest. The paper presents initial psychometric validation of the Psi-Q including factor analysis, internal consistency of the entire scale and modality-specific subscales, and relationship to other measures of trait imagery. Due to the similarity of the Psi-Q to the QMI and VVIQ in obtaining vividness ratings, and the derivation of all three measures from Bett's QMI, we first compared it to the Spontaneous Use of Imagery Scale (SUIS; Reisberg, Pearson, & Kosslyn, 2003) to evaluate its construct validity.

The SUIS measures the tendency to use mental imagery in a range of everyday situations. We also present an initial validation of a short-form of the Psi-Q in light of commonly held criticisms that existing multi-modal measures of imagery vividness (e.g., Sheehan, 1967) are excessively long and time-consuming to complete.

Study 1: Exploratory Factor Analysis

Method

Scale construction

Two of the authors (JA, SB) reviewed published versions of the QMI and VVIQ, and generated new items, with an aim of developing a set of items that sampled broadly across and within sensory modalities, assessing imagery for familiar and distinct sensations while avoiding items that might provoke very easy or stereotyped responses (for example, we selected ‘excited’ and ‘furious’ as emotional imagery items rather than ‘happy’ and ‘sad’ on this basis). We retained two items from Sheehan’s (1967) shortened QMI, reworded eight, and added 25 new items (see Table 1 for all Psi-Q items). Specifically, Sheehan’s visual scale contained four questions on the appearance of a friend and one on ‘the visual image you hold before your eyes when you think of a setting sun’. We reworded one item as ‘a friend you know well’, and a second as ‘a sunset’. From Sheehan’s auditory scale we reworded ‘the clapping of hands of applause’, the horn of a car’ and ‘the meowing of a cat’, but replaced ‘the whistle of train’ and ‘the sound of escaping steam’. From the ‘cutaneous’ scale, we retained ‘fur’, reworded ‘sand’ and ‘a pinprick’, and dropped ‘a luke-warm bath’ and ‘linen’. From the ‘olfactory’ scale, we retained ‘a stuffy room’, reworded ‘freshly applied paint’, and dropped ‘boiling vegetables’, ‘roasting meat’ and ‘leather’. As taste and olfactory imagery are implicated in substance craving, we avoided items related to appetitive food and drink as far as possible. For the remaining three scales we developed 15 new items.

Participants

A total of 419 participants (79 males, 340 female), aged between 18.4 and 62.0 years (median 21.8), completed an online survey advertised on the University website and through the online School of Psychology research participation system. All but six were in the UK, and all but three indicated that they were fluent in English. 225 were studying Psychology at the University and completed the surveys for participation points that they could use to reward participants in their own research. Of the remaining 193, 39 were undergraduates, 20 were not associated with a University, and 134 were staff or postgraduates.

Materials

Plymouth Sensory Imagery Questionnaire (Psi-Q) This consisted of seven sets of five items, each set having a heading such as ‘Imagine the appearance of…’.and then five items (see Table 1 for content). Participants were asked to rate their image on an eleven-point scale anchored by ‘no image at all’ (0) and ‘as vivid as real life’ (10).

Spontaneous Use of Imagery Scale (SUIS; Reisberg, Pearson & Kosslyn, 2003). This contained twelve items, presented on a single page, which asked respondents to rate how often they engaged in visual imagery in their everyday activities. Typical items include ‘If I am looking for new furniture in a store, I always visualize what the furniture would look like in particular places in my home’ and ‘When I first hear a friend’s voice, a visual image of him or her almost always springs to mind' The items were rated on a five point scale, anchored Never (1), About half the time (3), and Always (5).

The SUIS and then the Psi-Q were presented as separate pages within the online survey, which also contained pages on smoking and intrusive thoughts (these are not reported here). Unlike the VVIQ, no instructions were given about keeping eyes open or shut, which is not necessary for the SUIS, nor relevant for 30 of the Psi-Q items.

Procedure

Ethical consent for the study was obtained from the Faculty of Science and Technology Ethics Committee at Plymouth University. On accessing the link to the study, participants read a short description of the study and gave consent to take part. At the end of the survey they were thanked for participation and asked to pass the link on to their friends and colleagues.

Results

The mean score obtained on the SUIS was 3.43 (*SD* = 0.62), with scores ranging over almost the entire scale from 1.33 to 4.83. These scores are comparable to those reported by Reisberg et al., (2003), who obtained a mean of 3.11 (*SD* = 0.66).

Eleven participants selected the maximum answer of 10 for all of the Psi-Q items, and four others gave the same rating for all or all but one item, and so were excluded from further analysis. The overall mean of the Psi-Q for the remaining 404 participants was 7.05 (*SD* = 1.61), with scores ranging from 1.11 to 9.94. Only 35 participants scored below 6, suggesting that most people were able to construct the images described by the items. The scale produced a Cronbach's alpha of 0.96, with no improvement indicated by deleting any items. The Psi-Q items met the criteria for sampling adequacy (KMO = 0.95, Bartlett's test of Sphericity $p < .001$) and so were then entered into a factor analysis (SPSS19, maximum likelihood, oblimin rotation), and seven factors were found with eigen-values > 1. A seven-factor extraction (Goodness of fit test: $\chi^2(371)=889$) corresponded to the seven imagery modalities (Table 1), with each item within a modality producing its strongest loading on the appropriate factor (all >.50), and with some items also having a weaker cross-loading on another factor (all between .50 and .60). Only one item in the visual, auditory and emotional factors produced such cross-loadings ('the sound of hands clapping' also loading on touch, which makes intuitive sense), but smell and taste produced several cross-loadings with each other, and the touch and body factors produced a variety of item-specific cross-loadings. A six factor solution combined the factors of Touch and Body but had a significantly worse fit ($\chi^2(400)=1075$; χ^{2-}change(29)=186, p<.005), and a five-factor solution additionally combined Smell with Taste, and further worsened fit ($\chi^2(430)=1370$; χ^{2-}change(30)=295, p<.005). The seven-factor solution retaining each modality was selected on grounds of interpretability and goodness of fit.[1]

Insert Tables 1 and 2 about here

[1] As we had generated our items to produce seven modality specific subscales, a reviewer suggested that we ought to have used Confirmatory Factor Analysis in this study, rather than Exploratory Factor Analysis. Accordingly we repeated the analyses using CFA and found results consistent with those reported here.

To examine the possible existence of a higher order vividness factor, mean scores were obtained for each of the imagery modalities (Table 2), and as these subscale means also met criteria for sampling adequacy (KMO = .892, Bartlett's test of sphericity $p < .001$) a further factor analysis (SPSS19, maximum likelihood, oblimin) was attempted. This found only one factor with an eigen-value > 1, (χ^2 (14)= 90.2, $p < .001$), and the scree test indicated one or two factors. The minimum correlation between subscale means was .29 (vision – emotion), with all others between .40 and .71 (body-touch). A two factor extraction was attempted but this made fit worse (χ^2 (8)= 47.3, p <.001; χ^2-change(6)=41.9, p<.001), with the pattern matrix clustering the first five subscales (vision, sound, smell, taste and touch) on one factor, and the last two (body and emotion) on the second, although all subscales had loadings of .48 or above in the structure matrix. The one-factor solution for the second order structure is selected on the basis of eigen-values and goodness of fit tests.

The SUIS scores correlated with the overall Psi-Q mean and with each of the imagery modality subscales (Table 2). Unsurprisingly, given the visual nature of the SUIS items, the highest correlation was with the vision subscale. Other correlations, although significant, were weak or negligible, reflecting differences between the Psi-Q in assessing modality-specific imagery vividness, and the SUIS assessing general tendency to use visual imagery.

An obvious question that these data can answer is whether people report a consistent profile in their imagery vividness, being above or below average across all modalities, or whether there exist individual differences in imagery profiles. As the correlations between modalities indicate, people tend to give similar mean ratings for each modality, but this may reflect idiosyncratic use of the scale, with differing interpretations of what is meant by ‘vivid’. To remove the gross differences in mean vividness we normalized scores within participant (for all 35 items, subtracting their personal mean and dividing by their personal standard deviation), and then found the mean for each modality. A score above zero would indicate that the modality was above that person’s mean; a score below zero indicates that the modality is below a person’s mean. In order of relative strength, vision produced a normalized mean of .46, touch .20, sound .08, body .03, emotion -.09, taste -.24, and smell -.43. These values indicate that vision and touch were the easiest modalities for people to imagine, and taste and smell the hardest. We then classified people as being ‘high’ in imagery for a modality if they were in the top third of the sample (N=133) on these standardized scores, and ‘low’ if they were in the bottom third (N=133). Over the whole sample, no-one was in the middle third for all modalities, only two were not in the bottom third for at least one modality, and only five were not in the top third for at least one modality; apart from these seven individuals, everyone was in the top third for at least one and the bottom third for another modality. For the most obvious contrast, vision-sound, 39 people (10%) were in the top third on vision but the bottom third on sound, and 33 (8%) were in the bottom third on vision, but the top third on sound. 51 (13%) were in the top third for both and 51 (13%) in the bottom third for both. There was no association between these two modalities $\chi^2(4, N=404)=1.04$, $p=.10$.

Test-retest reliability

Twenty-two months after the first survey, 62 of the 225 psychology undergraduates who were still attending Plymouth University were recontacted by email and asked to complete the Psi-Q and SUIS a second time, again in an online survey and in return for a participation point. This allowed us to compute test re-test reliability measures for both scales. Altogether 41 of the 62 completed the second set of tests (8 male). The means for this sample did not differ between test and retest (SUIS $t(40)=1.7$, $p=.09$; Psi-Q $t(40)=0.83$, $p=.41$).

At retest, both scales showed good internal reliability: Psi-Q .97; SUIS .74; and the two scales correlated .40 overall (SUIS and the Vision subscale correlating .48). Overall, the test-retest reliability of SUIS was .53, and for Psi-Q .71. The subscales of the Psi-Q also showed good test-retest reliability, ranging from .84 (bodily sensation) to .43 (touch). The comparatively low value for touch is due to poor test-retest correlations for individual items in the subscale: the correlations for warm sand ($r=.25$), icy water ($r=.30$) and fur ($r=.31$) were among the lowest eight of the 35 items. Bodily sensation, on the other hand, contained the three items with the highest test-retest correlations: walking briskly ($r=.67$), relaxing in a warm bath ($r=.73$), and threading a needle ($r=.74$).

Study 2: Confirmatory Factor Analysis

Method

Participants

Data were obtained from a further 223 participants (82 Males, 141 females; aged between 17 and 66, with a mean of 23.2 and a median of 21) taking part in an online study on “mental imagery, personality and mood” (additional data on personality and mood are not reported here). Twelve participants were identified who had also completed Study One, and so their data were not included in the analysis.

Materials

The Psi-Q was unaltered from Study 1 except that responses were made on a seven-point scale (1-7) instead of the eleven point scale (0-10) used in Study 1.

Procedure

Ethical consent for the study was obtained from the Faculty of Science and Technology Ethics Committee at Plymouth University. Recruitment took the form of emails to students and staff, and advertisements placed on campus. On accessing the study hyperlink, participants were presented a short description of the study and confirmed consent to take part. On completion of the survey participants were thanked and asked to enter their email address if they wished to be entered into a prize draw.

Results

After rejecting two participants who had given the maximum response of 7 to all or all but one of the Psi-Q items, data met assumptions of sampling adequacy (KMO = .897; Bartletts' Test of Sphericity $p < .001$) and produced a Cronbach's alpha of 0.93. We compared the seven factor structure obtained from Study 1 with a model including an additional second order Imagery factor, with a single Imagery factor model, and with an eight factor model that included a Common Method Variance factor linked to each item to test for bias due to the use of a common response format and all items being rated at a single, online testing session (Podsakoff, MacKenzie, Lee & Podsakoff, 2003). We examined the effect of including this factor upon standardized regression weights (a reduction >.2 being considered as indicating a contribution of common method variance).

We compared the models using change in the model χ^2 values, and also examined the models' χ^2/df ratios (values greater than 3 indicating poor fit), their comparative fit indices (CFI, values <.95 indicating poor fit) and their root mean square error of approximation (RMSEA, values >.05 indicating poor fit), with the PClose statistic being used to test whether the RMSEA was greater than the .05 threshold. Preliminary diagnostic tests conducted within AMOS19 indicated that the data did not meet assumptions for multivariate normality, with all items being negatively skewed, and so scores were reversed (subtracted from 8) and then log transformed. Following this, several items still had skewness or kurtosis values with critical ratios >2, and so we included a bootstrapping method (2000 iterations) to compute a Bollen-Stein corrected probability value for the model fit (p values <.05 indicating poor fit).We also examined the Akaike Information Criterion (AIC), where lower values indicate better fit and parsimony (see Table 3).

Insert Table 3 about here

The seven-factor model of Study 1 was applied first, with modification indices being examined to specify covariance between measurement errors within the same factor. Overall model fit was good, with all goodness of fit criteria indicating adequate fit (Table 3, Model 1), and all regression weights were statistically significant at $p < .001$. Modification indices indicated that the sound item 'imagine the sound of children playing' loaded on four other factors, and so the model was reevaluated without this item, improving fit significantly (Table 3 Model 2; change-$\chi^2(33)=77$, $p<.001$).

No other simple modification could be found that produced a better fit. The addition of a second order imagery factor produced a significantly worse fit (Table 3

Model 3; change-$\chi^2(14)=111$, $p<.001$), and a single factor imagery solution failed on all goodness of fit criteria (Table 3, Model 4). Adding a Common Method Variance factor to the full 7-factor model improved fit further (Table 3, Model 5; change-$\chi^2(35)=114$, $p<.001$) but no regression weights fell by more than .06, and so common method variance does not seem to be affecting this analysis.

The complete Psi-Q was then compared with a shortened form retaining three items from each modality with the highest factor loadings from Study One (indicated with asterisks in Table 1). The shortened 21-item scale included only five items based upon the original QMI items, and 16 new items. The seven factor model again fitted this set of items well according to all criteria (Table 3, Model 6), and adding a Common Method Variance factor again improved fit significantly (Table 3, Model 7; change-$\chi^2(21)=62$, $p<.001$), to the extent that the overall model χ^2 also now indicated good fit ($p=.082$), but again none of the regression weights fell by more than 0.175, indicating little substantial influence of common method variance. Cronbach's alpha for these 21 items was 0.91, and Subscale and Total scores were all highly correlated with their full-scale counterparts, all $r > .89$.

Study 3: External Validity

As a final check on the external validity of the Psi-Q, we compared it against the widely used VVIQ-2 (Marks, 1995).

Method

Participants

A total of 212 (59 Male) participants aged between 18.4 and 66.0 years (median 23.4) took part in an online questionnaire advertised through the School of

Psychology participation system and the University web pages. 148 participants were undergraduate students, and 30 were postgraduate students or academic staff. 48 of the undergraduates received a participation point for completing the survey (which they could use to reward participants in their own studies), and all other participants were entered into a prize draw for a £20 voucher.

Materials

Psi-Q: We presented the full version of the Psi-Q (Table 1) with the 11-point response scale used in Study 1, anchored ‘No image at all’ and ‘As vivid as real life’.

Vividness of Visual Imagery Questionnaire (VVIQ-2; Marks, 1995). This consisted of four sets of four items, with each set asking respondents to imagine a particular scene, with their eyes open, and then answer four questions about the vividness of details within their image. The first set, for example, is based on the QMI and asks respondents to imagine a friend ‘whom you frequently see’, and then asks about ‘the exact contour of face, head, shoulders and body’, ‘characteristic poses of head, attitudes of body, etc’, ‘the precise carriage, length of step, etc in walking’, and ‘the different colours worn in some familiar clothes’. The other sets refer to ‘the rising sun’, ‘the front of a shop’, and ‘a country scene’. We asked respondents to use the same rating options as Marks (1995), i.e., ‘no image at all, you only “know” that you are thinking of an object’, ‘vague and dim’, ‘moderately clear and vivid, ‘clear and reasonable vivid’ and ‘perfectly clear and vivid as normal vision’, but unlike the original, the least vivid was placed at the left and no numerical values were used, with respondents checking a circle.

The online survey first collected demographic details, and then presented some questions about participants' smoking habits (as part of another study). Participants then completed the 35 item Psi-Q, followed by the 16-item VVIQ-2.

Results

The long form of the Psi-Q (M=5.8, SD=1.8) and the shorter 21 item form (M= 6.7, SD=1.8) correlated r=.99 (p<.001), with subscales from the two forms correlating r>.95. Cronbach's alpha for the long form was .96, for the short form .94.

Both totals correlated with the VVIQ-2 (M=3.4, SD=0.8): Psi-Q r=.67, p<.001, Short form r=.66, p<.001. The subscales from the Psi-Q all correlated with the VVIQ-2, ranging from r=.44 (short version, taste) to r=.60 (long version, auditory and touch). The Vision subscale correlated with the VVIQ-2 r=.52 (long version) and r=.51 (short version), in the middle of the range of correlations.

Discussion

In contrast to previous evidence supporting a single factor of general imagery vividness on the short form of the QMI (White, et al., 1974; 1978; see also review by Richardson, 1994), our findings indicate that differences in imagery vividness between sensory modalities may be detected using sensitive and appropriate measures such as the Psi-Q. The shorter 21-item scale, with three items for each modality, performed as well as the longer version, and as at least one of the items from the longer form showed cross-loadings, the short form may be more appropriate for future use.

The finding that different modalities of imagery are separable in terms of self-reported vividness is consistent with neuroscientific research demonstrating modality specific patterns of activation for both imagery and perception (Ganis et al., 2004; Plailly, Delon-Martin, & Royet, 2012; Schendan & Ganis, 2012). Different modalities of imagery have also been shown to dissociate both in healthy volunteers using experimental manipulations, and in neuropsychological patients following selective and specific damage to cerebral structures (Sirigu & Duhamed, 2001). These findings converge with theoretical working memory models proposing that the vividness of mental imagery is partly determined by the availability of modality-specific resources which maintain and manipulate information from long-term memory (Andrade, Kavanagh, & Baddeley, 1997; Baddeley & Andrade, 2000; Lilley, Andrade, Turpin, Sabin-Farrell, & Holmes, 2009). The findings are also consistent with theories that assume that imagery involves reactivation of associated perceptual, affective and motor information (Barsalou, 1999, 2008; Lang, 1979).

Baddeley (1986) entertained the possibility that there would be temporary memory stores for modalities other than visual and auditory, but this idea has received little attention beyond some research on olfactory short-term memory (Andrade & Donaldson, 2007; Dade, Zatorre, Evans, & Jones-Gotman, 2001; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Zelano, Montag, Khan, & Sobel, 2009). Future research should test whether Baddeley and Andrade’s (2000) model of image vividness generalizes to imagery in the other modalities identified in the current study, including whether there are modality-specific short-term memory stores beyond those for auditory, visual and olfactory information.

Although the vividness of imagery is to a certain extent modality-specific, the strong correlations between factors in the Psi-Q suggest some common factors are influencing performance, although the confirmatory factor analysis indicated that common method variance (Podsakoff et al., 2003) was not playing a large role. In the exploratory analysis of Study 1 we did find a single second-order factor, but adding a second order ‘imagery’ factor to the confirmatory analysis in Study 2 worsened fit, so further work is needed to determine the relationships between the modality specific factors; this should ideally be driven by theoretical considerations. Experimental work by Baddeley and Andrade (2000) showed that general task load reduces the vividness of visual and auditory imagery, in addition to the detrimental effects of modality-specific interference from concurrent tasks (see also Gunter & Bodner, 2008). The episodic buffer component of working memory has been proposed to account for such findings (Baddeley, 2000). The episodic buffer interacts with long-term memory and forms a limited capacity temporary store for multi-modal representations, contributing to the vividness of multi-sensorial imagery. Where images are dynamic, such as images of complex sounds, changing scenes or body movements, executive processes are likely to be involved in manipulating and updating stored sensory representations (Baddeley & Andrade, 2000). The relative contributions of the episodic buffer, central executive, and modality-specific stores to imagery and image vividness in different modalities are as yet unknown. The Psi-Q provides a way of measuring and equating image vividness in such research.

In the Introduction, we noted that disturbances in imagery are associated with a number of clinical disorders including social phobia, post-traumatic stress disorder, unipolar and biopolar depression and addiction. By assessing the vividness of imagery in multiple modalities within a single questionnaire, the Psi-Q allows the identification of the modalities which may be particularly relevant to a given disorder (or state), and impact of this state on imagery in other modalities. For example, are individuals with vivid taste imagery more prone to cravings for food or alcohol? The Psi-Q also offers the potential to test the relationship between trait imagery and vulnerability to psychological disorders. Assessing imagery across modalities is likely to be critical in this regard. For example, heightened imagery has been proposed to be a trait marker for schizotypy, but this relationship is only apparent when imagery for a range of modalities has been assessed, rather than merely visual imagery (Bell & Halligan, 2010; Oertel, Rotarska-Jagiela, van de Ven, et al., 2009).The relationship between perception and the vividness of imagery in different modalities is a further area for research. Neuropsychological patients typically show deficits in visual imagery corresponding to perceptual deficits (Farah, 1988; Kosslyn, 2005; Kosslyn, Maljkovic, Hamilton, Horwitz, & Thompson, 1995), but this is not always the case. Vivid visual imagery in the form of behavioural performance and neural activation has been reported in a patient with near-complete cortical blindness (Bridge, Harrold, Holmes, Stokes, & Kennard, 2012). Conversely, selective deficits to visual imagery have been found in patients with intact visual perception (Zeman, Della Sala, Torrens, et al., 2010). However, these studies have typically focused on measuring imagery only in the visual modality. Psi-Q offers the potential to expand this work, for example, to test the impact of impairment to visual imagery on imagery in different modalities, and to test the impact of other sensory impairments to imagery in other modalities.

In conclusion, in our development and initial validation of Psi-Q we address the need for a sensitive and valid multi-modality measure of image vividness for application in cognitive, neuroscientific, and clinical research, as well as imagery research per se. Consistent with working memory models, scores on the Psi-Q are subject to modality-general and modality-specific factors. Future research is needed to delineate the relative contributions of modality-general and modality-specific aspects of cognitive and neural function to the vividness of imagery in each modality.

References

Andrade, J., Kavanagh, D. J., & Baddeley, A. D. (1997). Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder. *British Journal of Clinical Psychology, 36(2)*, 209-223. DOI: 10.1111/j.2044-8260.1997.tb01408.x

Andrade, J. & Donaldson, L. (2007). Evidence for an olfactory store in working memory? *Psychologia, 50(2),* 76–89. DOI: 10.2117/psysoc.2007.76

Baddeley, A. D. (1986) *Working Memory.* Oxford, England: Oxford University Press.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 126-145. DOI: 10.1016/S1364-6613(00)01538-2

Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology-General, 129(1)*, 126-145. DOI: 10.1037/0096-3445.129.1.126

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22,* 577–660.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–45. DOI: 10.1146/annurev.psych.59.103006.093639

Bell, V., & Halligan, P. W. (2010). Additional data on whether vividness of visual mental imagery is linked to schizotypal traits in a non-clinical population. *Psychiatry Research, 178(3),* 568-569. DOI: 10.1016/j.psychres.2009.05.003

Betts, G. H. (1909). *The distribution and functions of mental imagery*. New York: Columbia University.

Braun, S. M., Beurskens, A. J., Borm, P. J., Schack, T., & Wade, D. T. (2006). The effects of mental practice in stroke rehabilitation: A systematic review.

Archives of Physical Medicine and Rehabilitation, 87(6), 842-852. DOI: 10.1016/j.apmr.2006.02.034

Bridge, H., Harrold, S., Holmes, E. A., Stokes, M., & Kennard, C. (2012). Vivid mental imagery in the absence of the primary visual cortex. *Journal of Neurology, 259(6), 1062-1070*. DOI: 10.1007/s00415-011-6299-z

Bywaters, M., Andrade, J., & Turpin, G. (2004). Determinants of the vividness of visual imagery: The effects of delayed recall, stimulus affect and individual differences. *Memory, 12(4)*, 479-488. DOI: 10.1080/09658210444000160

Campos, A. & Perez-Fabello, M.J. (2005). The Spanish Version of Betts' Questionnaire Upon Mental Imagery, *Psychological Reports, 96*, 51-56. DOI: 10.2466/pr0.96.1.51-56

Callow, N., Roberts, R., & Fawkes, J. Z. (2006). Effects of dynamic and static imagery on vividness of imagery, skiing performance and confidence. *Journal of Imagery Research in Sport and Physical Activity, 1*, 1–13. DOI: 10.2202/1932-0191.1001

Cross, E. S., Kraemer, D. J. M., Hamilton, A. F. d. C., Kelley, W. M., & Grafton, S. T. (2009). Sensitivity of the Action Observation Network to Physical and Observational Learning. *Cerebral Cortex, 19*, 315-326.

Cui, X., Jeter, C. B., Yang, D., Montague, P. R., & Eagleman, D. M. (2007). Vividness of mental imagery: Individual variabiltiy can be measured objectively. *Vision Research, 47(4),* 474-478. DOI: 10.1016/j.visres.2006.11.013

Dade, L. A., Zatorre, R. J., Evans, A. C., & Jones-Gotman, M. (2001). Working Memory in Another Dimension: Functional Imaging of Human Olfactory Working Memory. *Neuroimage, 14(3)*, 650–660. DOI: 10.1006/nimg.2001.0868

Daselaar, S. M., Porat, Y., Huijbers, W., & Pennartz, C. M.A. (2010). Modality-specific and modality-independent components of the human imagery system. *Neuroimage, 52(2)*, 677–85. DOI: 10.1016/j.neuroimage.2010.04.239

Dean, G. M., & Morris, P. E. (2003). The relationship between self-reports of imagery and spatial ability. *British Journal of Psychology, 94(2)*, 245–73. DOI: 10.1348/000712603321661912

Farah, M. J. (1988). Is visual imagery really visual? Overlooked evidence from neuropsychology. *Psychological Review, 95(3),* 307-317. DO: 10.1037/0033-295X.95.3.307

Galton, F. (1883). *Inquiries into human faculty and its development*. London: Macmillan.

Ganis, G., Thompson, W. L., & Kosslyn, S. M. (2004). Brain areas underlying visual mental imagery and visual perception: An fMRI study. *Cognitive Brain Research, 20(2),* 226-241. DOI: 10.1016/j.cogbrainres.2004.02.012

Gilbert, A.N., Crouch, M., & Kemp, S.E. (1998). Olfactory and visual mental imagery. *Journal of Mental Imagery, 22,* 137-146.

Gunter, R. W., & Bodner, G. E. (2008). How eye movements affect unpleasant memories : Support for a working-memory account. *Behaviour Research and Therapy, 46,* 913–931. DOI: 10.1016/j.brat.2008.04.006

Hackmann, A., Bennett-Levy, J., & Holmes, E. A. (2011). *Oxford guide to imagery in cognitive therapy.* Oxford: Oxford University Press.

Hales, S. A., Deeprose, C., Goodwin, G. M., & Holmes, E. A. (2011). Cognitions in bipolar disorder versus unipolar depression: Imagining suicide. *Bipolar Disorders, 13(7-8)*, 651-661. DOI: 10.1111/j.1399-5618.2011.00954.x

Hall, C.R., & Martin, K.A. (1997). Measuring movement imagery abilities: a revision of the Movement Imagery Questionnaire. *Journal of Mental Imagery, 21,* 143–154.

Herholz, S. C., Halpern, A. R., & Zatorre, R. J. (2012). Neuronal correlates of perception, imagery, and memory for familiar tunes. *Journal of Cognitive Neuroscience, 24(6),* 1382–97. DOI: 10.1162/jocn_a_00216

Hirsch, C. R., & Clark, D. M. (2007). Imagery special issue: Underestimation of auditory performance in social phobia and the use of audio feedback. *Journal of Behavior Therapy and Experimental Psychiatry, 38(4)*, 447-458. DO: 10.1016/j.jbtep.2007.08.004

Holmes, E. A., Arntz, A., & Smucker, M. R. (2007). Imagery rescripting in cognitive behaviour therapy: Images, treatment techniques and outcomes. *Journal of Behavior Therapy and Experimental Psychiatry, 38(4)*, 297-305. DO: 10.1016/j.jbtep.2007.10.007

Holmes, E. A., Crane, C., Fennell, M. J. V., & Williams, J. M. G. (2007). Imagery about suicide in depression - "Flash-forwards"? *Journal of Behavior Therapy and Experimental Psychiatry, 38(4)*, 423-434. DO: 10.1016/j.jbtep.2007.10.004

Holmes, E. A., Grey, N., & Young, K. A. D. (2005). Intrusive images and "hotspots" of trauma memories in posttraumatic stress disorder: An exploratory investigation of emotions and cognitive themes. *Journal of Behavior Therapy and Experimental Psychiatry, 36(1),* 3-17. DOI: 10.1016/j.jbtep.2004.11.002

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review, 30(3),* 349-362. DO: 10.1016/j.cpr.2010.01.001

Isaac, A.R., Marks, D.F., & Russell, D.G. (1986). An instrument for assessing imagery of movement. The vividness of movement imagery questionnaire. *Journal of Mental Imagery, 10,* 23–30.

Jackson, J. (2005). My dance and the idea body: looking at ballet practice from the inside out. *Research in Dance Education, 6,* 25-40. DO: 10.1080/14617890500373089

Kavanagh, D. J., Andrade, J., & May, J. (2005). Imaginary relish and exquisite torture: The elaborated intrusion theory of desire. *Psychological Review, 112(2)*, 446-467. DOI: 10.1037/0033-295X.112.2.446

Kavanagh, D. J., May, J., & Andrade, J. (2009). Tests of the Elaborated Intrusion Theory of Craving and Desire: Features of alcohol craving during treatment for an alcohol disorder. *British Journal of Clinical Psychology, 48*, 241–254. DO: 10.1348/014466508X387071

Kosslyn, S. M. (2005). Mental images and the brain. *Cognitive Neuropsychology, 22(3),* 2333-2347. DOI: 10.1080/02643290442000130

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience, 2(9)*, 635-642. DOI: 10.1038/35090055

Kosslyn, S. M., Maljkovic, V., Hamilton, S. E., Horwitz, G., & Thompson, W. L. (1995). Two Types of Image Generation - Evidence for Left and Right-Hemisphere Processes. *Neuropsychologia, 33(11),* 1485-1510. DOI: 10.1016/0028-3932(95)00077-G

Kosslyn, S. M., Margolis, J. A., Barrett, A. M., Goldknopf, E. J., & Daly, P. F. (1990). Age differences in imagery abilities. *Child Development, 61*, 995–1010. DOI: 10.2307/1130871

Kozhevnikov, M., Motes, M. A., & Hegarty, M. (2007). Spatial visualization in physics problem solving. *Cognitive Science, 31*, 549-557. DOI: 10.1080/15326900701399897

Krasnow, D. H., Chatfield, S. J., Barr, S., Jensen, J. L., & Dufek, J. S. (1997). Imagery and conditioning practices for dancers. *Dance Research Journal, 29,* 43-64. DOI: 10.2307/1478236

Lang, P. J. (1979). A Bio-Informational Theory of Emotional Imagery. *Psychophysiology, 16(6)*, 495–512. DOI: 10.1111/j.1469-8986.1979.tb01511.x

Lilley, S. A., Andrade, J., Turpin, G., Sabin-Farrell, R., & Holmes, E. A. (2009). Visuospatial working memory interference with recollections of trauma. *British Journal of Clinical Psychology, 48(3)*, 309-321. DOI: 10.1348/014466508X398943

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology, 64(2)*, 17-24. DOI: 10.1111/j.2044-8295.1973.tb01322.x

Marks, D. F. (1995). New directions for mental imagery research. *Journal of Mental Imagery, 19,* 153-167.

May, J., Andrade, J., Panabokke, N., & Kavanagh, D. J. (2004). Images of desire: Cognitive models of craving. *Memory, 12(4),* 447 – 461. DOI: 10.1080/09658210444000061

May, J., Calvo-Merino, B., deLahunta, S., McGregor, W., Cusack. R, Owen, A.M., … Barnard, P. (2011). Points in mental space. *Dance Research 29(2)*, 404-432. DOI: 10.3366/drs.2011.0026

McAvinue, L.P. & Robertson, I.H. (2006-7). Measuring visual imagery ability: a review. *Imagination, Cognition And Personality, 26(3)*, 191-211. DOI: 10.2190/3515-8169-24J8-7157

McNorgan, C. (2012) A meta-analytic review of multisensory imagery identifies the neural correlates of modality-specific and modality-general imagery. *Frontiers in Human Neuroscience, 6,* Article 285. DOI: 10.3389/fnhum.2012.00285

Morina, N., Deeprose, C., Pusowski, C., Schmid, M., & Holmes, E. A. (2011). Prospective mental imagery in patients with major depressive disorder or anxiety disorders. *Journal of Anxiety Disorders, 25(8)*, 1032–7. DOI: 10.1016/j.janxdis.2011.06.012

Morris, P. E., & Gale, A. (1974). A correlational study of variables related to imagery. *Perceptual and Motor Skills, 38(2),* 659–65. DOI: 10.2466/pms.1974.38.2.659

Moulton, S. T., & Kosslyn, S. M. (2009). Imagining predictions: Mental imagery as mental emulation. *Philosophical Transactions of the Royal Society B, 364,* 1273-1280. DOI: 10.1098/rstb.2008.0314

Muse, K., McManus, F., Hackmann, A., & Williams, M. (2010). Intrusive imagery in severe health anxiety: Prevalence, nature and links with memories and maintenance cycles. *Behaviour Research and Therapy, 48(8)*, 792-798. DO: 10.1016/j.brat.2010.05.008

Oertel, V., Rotarska-Jagiela, A., van de Ven, V., Haenschel, C., Grube, M., Stangier, U., . . . Linden, G. D. J. (2009). Mental imagery vividness as a trait marker across the schizophrenia spectrum. *Psychiatry Research, 167,* 1 - 11. DOI: 10.1016/j.psychres.2007.12.008

Olivetti Belardinelli, M., Palmiero, M., Sestieri, C., Nardo, D., Di Matteo, R., Londie, A., . . . Romani, G. L. (2009). An fMRI investigation on image generation in different sensory modalities: The influence of vividness. *Acta Psychologica, 132,* 190-200. DOI: 10.1016/j.actpsy.2009.06.009

Pearson, J., Rademaker, R. L., & Tong, F. (2011). Evaluating the Mind's Eye: The Megacognition of Visual Imagery. *Psychological Science, 22(12),* 1535-1542.

Pearson, D. G., & Hollings, J. (2013). Einstein’s jacket: evidence for long-term perceptual specificity in mental imagery. *Consciousness and Cognition, 22(1),* 148–54. DOI: 10.1177/0956797611417134

Plailly, J., Delon-Martin, C., & Royet, J.-P. (2012). Experience induces functional reorganization in brain regions involved in odor imagery in perfumers. *Human Brain Mapping, 33(1),* 224–34. DO: 10.1002/hbm.21207

Podsakoff, P. M.,MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method bias in behavioral research- A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88,* 879-903. DOI: 10.1037/0021-9010.88.5.879

Pylyshyn, Z. (2003). Return of the mental image: Are there really pictures in the brain? *Trends in Cognitive Sciences, 7(3),* 113-118. 10.1016/S1364-6613(03)00003-2

Reason, M., & Reynolds, D. (2010). Kinesthesia, empathy and related pleasures: an inquiry into audience experience of watching dance. *Dance Research Journal, 2,* 49-75. DO: 10.1017/S0149767700001030

Reisberg, D., Pearson, D. G., & Kosslyn, S. M. (2003). Intuitions and introspections about imagery: The role of imagery experience in shaping an investigator's theoretical views. *Applied Cognitive Psychology, 17(2),* 147-160. DOI: 10.1002/acp.858

Richardson, A. (1994). *Individual differences in imaging: Their measurement, origins and consequences.* Amityville, New York: Baywood Publishing Company.

Roberts, R., Callow, N., Hardy, L., Markland, D., & Bringer, J. (2008). Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire. *Journal of Sport & Exercise Psychology, 30(2),* 200–221.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: The prospective brain. *Nature Reviews: Neuroscience, 8,* 657-661. DO: 10.1038/nrn2213

Schendan, H. E., & Ganis, G. (2012). Electrophysiological potentials reveal cortical mechanisms for mental imagery, mental simulation, and grounded (embodied) cognition. *Frontiers in Psychology, 3*, 329. DO: 10.3389/fpsyg.2012.00329

Schuster, C., Hilfiker, R., Amft, O., Scheidhauer, A., Andrews, B., Butler, J., . . . Ettlin, T. (2011). Best practice for motor imagery: A systematic literature review on motor imagery training elements in five different disciplines. *BMC Medicine, 9,* 75. DO: 10.1186/1741-7015-9-75

Schwartz, D. L., & Black, J. B. (1996). Analog imagery in mental model reasoning: depictive models. *Cognitive Psychology, 30,* 154-219. DOI: 10.1006/cogp.1996.0006

Sheehan, P. W. (1967). A shortened form of Betts questionnaire upon mental imagery. *Journal of Clinical Psychology, 23(3),* 386-389. DOI: 10.1002/1097-4679(196707)23:3<386::AID-JCLP2270230328>3.0.CO;2-S

Sirigu, A., & Duhamed, J. R. (2001). Motor and visual imagery as two complementary but neurally dissociable mental processes. J*ournal of Cognitive Neuroscience, 13*, 910-919. DO: 10.1162/089892901753165827

Statham, D. J., Connor, J. P., Kavanagh, D. J., Feeney, G. F. X., Young, R. M. D., May, J., & Andrade, J. (2011). Measuring alcohol craving: development of the Alcohol Craving Experience questionnaire. *Addiction, 106(7)*, 1230–8. DO: 10.1111/j.1360-0443.2011.03442.x

Wagman, R. & Stewart, C.G. (1974) Visual Imagery and Hypnotic Susceptibility. *Perceptual and Motor Skills, 38*, 815-822. DOI: 10.2466/pms.1974.38.3.815

Willander, J. & Baraldi, S. (2010) Development of a new Clarity of Auditory Imagery Scale. *Behavioral Research Methods, 42(3),* 785-90. DOI; 10.3758/BRM.42.3.785

White, K. D., Ashton, R., & Law, H. (1974). Factor Analysis of the shortened form of Bett's Questionnaire Upon Mental Imagery. *Australian Journal of Psychology, 26(3),* 183-190. DOI: 10.1080/00049537408255229

White, K. D., Ashton, R., & Law, H. (1978). The measurement of imagery vividness: Effects of format and order on the Bett's Questionnaire Upon Mental Imagery. *Canadian Journal of Behavioural Science, 10(1),* 68-78. DOI: 10.1037/h0081537

White, T. L., Hornung, D. E., Kurtz, D. B., Treisman, M., & Sheehe, P. (1998). Phonological and perceptual components of short-term memory for odors. *Annals of the New York Academy of Sciences, 855(3),* 635–7. DO: 10.1111/j.1749-6632.1998.tb10636.x

Yaguez, L., Nagel, D., Hoffman, H., M., C. A. G., Wist, E., & Homberg, V. (1998). A mental route to motor learning: Improving trajectorial kinematics through imagery training. *Behavior Brain Research, 90*, 95–106. DO; 10.1016/S0166-4328(97)00087-9

Zatorre, R. J., Halpern, A. R., & Bouffard, M. (2010). Mental Reversal of Imagined Melodies : A Role for the Posterior Parietal Cortex. J*ournal of Cognitive Neuroscience, 22(4),* 775–789. DO: 10.1162/jocn.2009.21239

Zelano, C., Montag, J., Khan, R., & Sobel, N. (2009). A specialized odor memory buffer in primary olfactory cortex. *PloS one, 4(3)*, e4965. DOI: 10.1371/journal.pone.0004965

Zeman, A. Z. J., Della Sala, S., Torrens, L. A., Gountouna, V.-E., McGonigle, D. J., & Logie, R. H. (2010). Loss of imagery phenomenology with intact visuo-spatial task performance: A case of 'blind imagination'. *Neuropsychologia, 48*, 145-155. D: 10.1016/j.neuropsychologia.2009.08.024

	M	*SD*	Vis	Aud	Smell	Taste	Touch	Body	Emo	CFA
Imagine the appearance of…										
*a bonfire	7.8	1.9	.80							.69
*a sunset	7.8	2.0	.79							.70
*a cat climbing a tree	7.3	2.3	.74							.53
a friend you know well	8.7	1.6	.56							.43
the front door of your house	8.6	1.9	.53							.46
Imagine the sound of…										
*the sound of a car horn	7.1	2.5		.86						.84
*hands clapping in applause	7.5	2.4		.82			.53			.72
*an ambulance siren.	7.4	2.4		.81						.70
the sound of children playing	6.8	2.5		.79						.68
the mewing of a cat	7.2	2.6		.73						.67
Imagine the smell of…										
*newly cut grass	6.8	2.7			.86					.80
*burning wood	6.3	2.8			.85	.57				.77
*a rose	5.8	3.0			.80	.56				.64
fresh paint	6.5	2.8			.79	.55				.82
a stuffy room	5.4	3.0			.66	.55				.66
Imagine the taste of										
*black pepper	6.0	2.9			.52	.86				.75
*lemon	7.2	2.5			.54	.77	.55			.82
*mustard	5.2	3.3			.54	.75				.57
toothpaste	7.4	2.3			.54	.68	.54			.81
sea water.	6.9	2.6			.59	.67	.53			.75
Imagine touching…										
*fur	7.5	2.4		.56	.54		.86			.70
*warm sand	7.4	2.4			.56		.84	.50		.73
*a soft towel	7.4	2.3		.56	.54	.50	.83	.54		.80
icy water	7.5	2.3					.79			.70
the point of a pin	7.3	2.4					.78	.55		.64
Imagine the bodily sensation of										
*relaxing in a warm bath	7.7	2.2			.51		.54	.82		.68
*walking briskly in the cold	7.7	2.1					.60	.75		.67
*jumping into a swimming pool	6.9	2.5						.72		.72
having a sore throat	7.2	2.5						.68	.52	.63
threading a needle	6.1	2.9					.51	.60		.61
Imagine feeling										
*excited	7.4	2.4							.87	.81
*relieved	7.0	2.6							.84	.80
*scared	6.6	2.7							.71	.64
furious	6.5	2.8							.66	.65
in love	6.8	3.0							.65	.53

Table 1: Means and Standard Deviations of Psi-Q items from Study One (0-10), with loadings >.50 on each factor on the seven-factor solution, and the standardised regression weights on the same factor in the confirmatory factor analysis of Study Two (CFA)

Note: Asterisked items (with the highest loadings in Study One) were retained in the short-form of the Psi-Q evaluated in Study Two

Table 2

Descriptive statistics from Study 1 for the seven imagery modality subscales of the Psi-Q, and correlations between the subscales, scale total and SUIS.

	M	*SD*	SUIS	Psi-Q	vision	sound	smell	taste	touch	body
vision	8.0	1.5	.33	.64						
sound	7.2	2.1	.20	.80	.56					
smell	6.2	2.4	.19	.84	.46	.60				
taste	6.5	2.2	.18	.81	.42	.56	.70			
touch	7.4	2.0	.19	.84	.44	.62	.65	.64		
body	7.1	2.0	.26	.85	.46	.58	.64	.62	.71	
emotion	6.9	2.1	.23	.68	.29	.46	.43	.40	.48	.59

Table 3. Fit indices from Study 2 CFA

Model	χ^2	df	χ^2/df	Bollen-Stein's p	CFI	RMSEA (90%CI)	PClose	AIC
1. 7-factor, 35 items	804	531	1.51	.091	.932	.048 (.041-.055)	.674	1002
2. 7-factor, 34 items	730	498	1.47	.144	.940	.046 (.038-.053)	.834	924
3. Model 2 + Imagery factor	841	512	1.64	.021	.915	.054 (.047-.060)	.163	1008
4. 1-factor, 35 items	1792	552	3.25	<.001	.692	.101 (.095-.106)	<.001	1948
5. Model 1 + CMV factor	690	496	1.39	.220	.952	.042 (.034-.049)	.967	957
6. 7-factors, 21 items	229	164	1.40	.200	.969	.042 (.028-.055)	.840	363
7. Model 6 + CMV factor	167	143	1.17	.519	.989	.028 (.000-.044)	.992	343

CFI: Comparative Fit Index; RMSEA (90%CI): Root mean square error approximation with 90% confidence interval; PClose: probability of RMSEA <.05; AIC: Akaike's Information Criterion; CM factor: Common Method factor.