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Principle component analyses of questionnaires measuring individual differences in synaesthetic phenomenology

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ABSTRACT

Questionnaires have been developed for categorising grapheme-colour synaesthetes into two sub-types based on phenomenology: associators and projectors. The general approach has been to assume a priori the existence of two sub-types on a single dimension (with endpoints as projector and associator) rather than explore, in a data-driven fashion, other possible models. We collected responses from 175 grapheme-colour synaesthetes on two questionnaires, the Illustrated Synaesthetic Experience Questionnaire (Skelton, Ludwig, & Mohr, 2009) and Rouw and Scholte's (2007) Projector–Associator Questionnaire. After Principle Component Analysis both questionnaires were comprised of two factors which coincide with the projector/associator distinction. This suggests that projectors and associators are not opposites of each other, but separate dimensions of experience (e.g. some synaesthetes claim to be both, others claim to be neither). The revised questionnaires provide a useful tool for researchers and insights into the phenomenology of synaesthesia.

1. Introduction

For individuals with synaesthesia, an 'inducer' in one modality (percept or concept) triggers a 'concurrent' experience in another modality. One of the most common types of synaesthesia is grapheme-colour (GC) synaesthesia (Simner et al., 2006), where viewing a letter, number or even grammatical symbol can induce a consistent (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007) and automatic (Mattingley, Rich, Yelland, & Bradshaw, 2001) colour experience. Although the experiences of individual synaesthetes are internally consistent, there are large differences between synaesthetes as to how they experience the colour. Each synaesthete has their own colour palette, the specific colours that they link with each grapheme, and although there are trends such as 'A' frequently being red (Simner et al., 2005) the actual colour that a synaesthete links to each grapheme, or the number of graphemes they have colour associations for, are not the only differences within this population.

GC synaesthetes have been roughly subdivided in previous research according to where they see their colour (Dixon, Smilek, & Merikle, 2004). Projectors are classified as those who 'see' the colour on the grapheme itself where it is located, for example if looking at a letter presented in black font on a piece of white paper, they would see the colour superimposed onto the grapheme on the paper. The associator category is wider, encompassing those who: 'see' the colours in their minds eye (irrespective of whether the colour is the same shape as the grapheme or a block of colour), 'see' the colour floating in

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space between the grapheme itself and the person, and people who simply 'know' that a grapheme is a certain colour. Two questionnaires have been developed and used extensively within synaesthesia research to determine which end of a continuous projector–associator dimension synaesthetes lie on. These are the Illustrated Synaesthetic Experience Questionnaire (ISEQ; Skelton, Ludwig, & Mohr, 2009) and Rouw and Scholte Projector–Associator Questionnaire (RSPA; Rouw & Scholte, 2007).

Support for this sub classification of GC synaesthesia has come from behavioural differences. Interference is found on a synaesthetic Stroop task when participants are presented with coloured graphemes that are incongruent with their synaesthetic experience (relative to congruent). This occurs for both projectors and associators. However, there are differences between projectors and associators depending on whether the task is to name the real colour (and ignore their synaesthesia) or name their synaesthetic colour (and ignore the real one) (Dixon et al., 2004). The authors predicted that projectors would demonstrate greater interference effects from photisms when having to name real colour, which they indeed observed. Projectors were faster at naming their photisms, whereas associators were faster at naming the real colour, which was also in line with their predictions. The results were presented as corroborating evidence for differences in synaesthetic phenomenology depending on the location of the concurrent photism. Other behavioural differences include a generally stronger correlation between similarly shaped graphemes (such as 'b' and 'd') and their concurrent colour in projectors compared to associators (Brang, Rouw, Ramachandran, & Coulson, 2011).

Differences in brain function, using fMRI, have also been found between projector and associator synaesthetes when presented with inducing relative to non-inducing graphemes. Associators activated areas linked to memory processes, and projectors activated more perceptual processing regions (Rouw & Scholte, 2010). Differences in functional connectivity with area V4 (involved in colour perception) also differ between synaesthetes with the fusiform gyrus implicated for projectors and the parietal lobe for associators (van Leeuwen, den Ouden, & Hagoort, 2011). Structural differences have also been measured with projector synaesthetes having greater inferior temporal cortex connectivity than associator synaesthetes, the subtypes were measured via Rouw and Scholte's (2007) Projector–Associator questionnaire. Therefore there is a range of evidence that differences, both behavioural and neurological, exist between the synaesthetic subtypes.

Although some differences have been measured between these sub groups, there are also instances where such a differentiation has not been observed. In one example, participants had to indicate the colour of a colour patch or black digit which was primed by the other (a colour primed a digit, or a digit primed a number) (Gebuis, Nijboer, & Van der Smagt, 2009). Incongruent pairings caused increased reaction times and P3 latency and amplitude differences in the ERP signal however no differences were found between projector and associator synaesthetes (note participants were only classified from direct questioning, not a specific questionnaire). Ward and colleagues found no significant difference between groups in an embedded figures test, where a global shape (square, rectangle, diamond or triangle) made up of local graphemic elements has been hidden within an array of graphemic distractors (Ward, Jonas, Dienes, & Seth, 2010). Although projector synaesthetes were more likely to report seeing a colour, there was no difference in behavioural performance. The evidence for behavioural differences between projectors and associators is therefore inconsistent.

Ward, Li, Salih, and Sagiv (2007) have argued that that the projector–associator distinction, as it is typically articulated, fails to account for more nuanced phenomenological reports. The term "mind's eye", for instance, tends to be used very inconsistently to describe a range of experiences. Some GC synaesthetes claim to see their colours inside their body (literally), others on a screen that has no physical location, and others claim to know the colour. All three would tend to be subsumed by the label 'associator'. Similarly, some synaesthetes claim to experience colours externally but 'in the air' (at a fixed location from the body) and others experience it on the text itself (i.e. at a location defined by the inducer itself). Both of these experiences tend to be classed as 'projector' but there is some evidence that they can be dissociated behaviourally (Ward et al., 2007). Rather than a dichotomy, Ward et al. (2007) argued for a multiplicity related to different spatial frames of reference (object-centred, body-centred, image-centred) and those who simply 'know' the colour. In a similar vein, van Leeuwen, Petersson, and Hagoort (2010) found differences using fMRI between those who project on a 'mental screen' (but not the grapheme itself) and those who have knowledge of colour associations.

The present research has two purposes: one methodological, and one theoretical. In terms of methodology, we will explore the factor structure and statistical reliability (inter-correlations of items) of two published questionnaires using Principle Component Analysis (PCA). At present it is assumed, but not proven, that the responses to all questions related to being, say, an 'associator' are highly inter-correlated. It is also assumed, but not proven, that all questions load on to a single factor solution (with endpoints of projector and associator). For instance, on the RSPA a synaesthetes' status as projector or associator is determined by subtracting the scores for associator questions from the projector questions. This tacitly assumes that all questions load on a single dimension rather than several dimensions. The analyses would also increase our theoretical understanding of synaesthetic phenomenology. For instance, some theories predict multiple sub-types of spatial phenomenology (Ward et al., 2007).

A more recent measure of synaesthetic experience is the Coloured Letters and Numbers (CLaN) questionnaire which is the only currently published synaesthesia questionnaire that has been analysed using Factor Analysis (more precisely, Maximum Likelihood Estimates) (Rothen, Tsakanikos, Meier, & Ward, 2013). This produced four distinct factors, localisation, automaticity/attention, deliberate use, and longitudinal changes. The localisation factor relates specifically to experiencing the colours localised on the grapheme ('projector') but, interestingly, questions that one might expect to relate to being an associator (e.g. knowing but not seeing the colour, less intense colours) were not negatively loaded on to the same factor (instead they tended to be excluded from the factor structure). This does not support the view that an associator is, statistically or theoretically, the opposite of a projector. Nor did it offer strong support for the view that there would be at least three subtypes of grapheme-colour synaesthesia based on spatial phenomenology (Ward et al., 2007). The present study directly compares the CLaN against the more established ISEQ and RSPA questionnaires.

2. Method

Participants were recruited through email invitation of a synaesthetic participant database at the University of Sussex. Demographic questions and the two questionnaires (ISEQ and RSPA, in that order) were hosted on Bristol Online Survey, completion took approximately 20 min and no monetary reimbursement was given to participants. There were 175 participants who completed the survey, 156 female, age range 15–78 ($M = 36.33$, SD = 16.22, age was not obtained for four participants).

Consistency was completed at a previous date (and recorded onto the database) by 67 participants using the Synaesthesia Battery (Eagleman et al., 2007) on which participants indicated the colour of their concurrent (if any) for the numbers 0–9 and alphabet. This is done three times, which allows the Synaesthesia Battery to calculate consistency of colour response for each grapheme. A score lower than one is considered to indicate a synaesthete (Eagleman et al., 2007) although this has been increased to 1.43 in a more recent analysis of online colour pickers (Rothen, Seth, Witzel, & Ward, 2013). Regardless of cut off, the lower the score, the more consistent the participant is for their colour choice. Also on the database were responses for CLaN which is a questionnaire designed to measure multiple dimensions of GC synaesthesia phenomenology. It was completed in the previous year and was hosted on Bristol Online Survey. The 16 questions comprise four factors which are; localisation, deliberate use, automaticity and attention, longitudinal changes. This questionnaire uses a five point Likert-scale (1 = strongly disagree, 5 = strongly agree). As the database containing CLaN and consistency scores was used for recruiting participants, we were able to match these measures recorded previously to the RSPA and ISEQ questionnaires hosted on Bristol Online Survey.

The Rouw and Scholte (2007) PA Questionnaire has 12 questions: six are designed to measure the trait of associating, and six for projecting. Responses are measured using a five point Likert scale (1 = strongly disagree, 5 = strongly agree). The synaesthete type is calculated by subtracting the mean associator score from the projector score, with negative values indicating associator and positive values a projector categorisation.

The Illustrated Synaesthetic Experience Questionnaire (Skelton et al., 2009) uses a seven point Likert scale (1 = least accurate, 7 = most accurate) to measure responses to five questions (3 associator, 2 projector). Each question has an accompanying image to demonstrate the particular grapheme and colour experience pairing in that question. To determine whether a synaesthete is a projector or associator, the mean associator score is subtracted from the mean projector score. The score must be greater than ±1 for a categorisation, values around zero are classified as "undetermined".

For our analyses, no initial grouping of questions are made because it is our aim to determine whether the categories of 'projector' and 'associator' emerge from a purely data-driven approach. As is standard practice for this method of analysis (Field, 2013), the data was analysed iteratively until all questions were included in a factor and such that each factor had internal validity and was reliable to the best the data would allow.

3. Results

3.1. Consistency comparisons

Consistency measures were known for 67 participants ($M = 0.78$, SD = 0.55). Only four participants had scores higher than 1.43.

In order to justify the use of the complete sample, we first ascertained whether there were any differences between those synaesthetes that had completed the consistency test and those that had not. For the RSPA a two (consistency group; measured or not) by 12 (RSPA question number; 1–12) way mixed measures ANOVA was conducted. The main effect of question was significant $F(3.97, 686.56) = 55.75$, $p < .001$ with Greenhouse–Geisser correction due to Sphericity violation. The main effect of consistency was not significant $F(1, 173) = 0.27$, $p = .60$. Homogeneity of Variance was violated for four questions, however as this was only one third of questions, transformation would impair analysis of the questions and the p value was very large ($p = .60$). Therefore it was considered that the two groups did not differ ($M = 2.99$, $SE = 0.06$ and $M = 2.94$, $SE = 0.05$ for synaesthetes who did and did not complete the consistency test, respectively). The interaction between consistency and RSPA question number was not significant $F(3.97, 686.56) = 55.75$, $p = .18$. In order to test whether the null hypothesis is supported, rather than there being insufficient evidence of a difference, a Bayes factor analysis was conducted (e.g. Dienes, 2011). A value less than 1/3 supports the null hypothesis, greater than 3 supports the alternative hypothesis, and between these values indicates insufficient evidence for either theory. A Bayes factor was calculated for each of the 12 questions, contrasting the group (consistency group; measured or not) using the values obtained from independent samples *t*-tests. The mean difference and SE values are included in Appendix A. A two tailed normal distribution, with a SD of 2 was used because, with a five point Likert scale, the maximum deviation from the central value is 2. Ten of the Bayes factors supported the null hypothesis, the other two (Q4 and Q9) indicated insufficient evidence for either hypothesis. This shows that the data from both groups was similar and can all be included in the factor analysis. The Bayes factor for each question can be seen in Appendix A.

For the ISEQ a two (consistency group; measured or not) by five (ISEQ question number; 1–5) way mixed measures ANOVA was conducted. There was a significant main effect of question F (3.44,594.18) = 58.48, $p < .001$ using Greenhouse–Geisser correction due to a violation of Sphericity. The main effect of consistency was not significant, F (1,173) = 0.02, $p = .88$ with the consistency measured ($M = 3.71$, $SE = 0.14$) being similar to consistency not measured ($M = 3.73$, $SE = 0.11$) participants. The interaction between consistency and ISEQ question was also not significant F (3.44,594.18) = 0.79, $p = .52$. Therefore there were not differences between the groups of participants. Bayes factors were calculated for the five questions contrasting the groups (consistency; measured or not) this time using 3 as the SD since the ISEQ uses a seven point Likert scale. All the Bayes factors supported the null hypothesis (see Appendix A) and therefore all data was included in the factor analysis.

PCA was run using Direct Oblimin rotation as colour localisation may be a continuum and therefore related aspects of a bimodal distribution. Absolute values under .4 were suppressed.

3.2. Rouw and Scholte PA Questionnaire (Rouw & Scholte, 2007)

Factor and reliability analyses

Initially, the data was tested to determine whether factor analysis was appropriate. The questions generally did not satisfy the assumption of normality. All items within the questionnaire should correlate with at least half the other questions, otherwise it suggests that it does not measure the same construct as the other questions. Q8 did not correlate significantly with half of the other questions and was therefore removed, after which all questions correlated significantly with at least half of the others. Q8 was "The colour is not on the paper but floats in space". The Determinant was well above the required value of .00001 (.003), the Keiser–Meyer–Olkin (KMO) measure of sampling adequacy was very good at .87 (Kaiser, 1974) and Bartlett's Test of Sphericity was highly significant (X (55) = 960.90, $p < .001$) therefore factor analysis was deemed appropriate for the data. Average communalities after extraction were adequate at .71. Three components with Eigenvalues over 1 were extracted initially, explaining a total of 70.71% of the variance however Kaiser's Criterion were not met therefore the Scree Plot (see Appendix B) was checked which suggested a two factor solution. The Factor Analysis was therefore repeated with a fixed two factor solution.

Average communalities after extraction was now reduced to .58 which is near adequate. The total variance explained was 58.17%, with Factor 1 accounting for 45.01% and Factor 2 an additional 13.15%. Q7 no longer loaded onto a factor, therefore it was removed and the analysis repeated. Q7 was "I do not see the letters/numbers literally in a colour but have a strong feeling that I know what colour belongs to a certain letter/number."

All questions still correlated significantly with at least half the others, the Determinant (.006), KMO (.89) and Bartlett's (X (45) = 866.93, $p < .001$) all deemed Factor Analysis suitable. Average communalities after extraction were .62. A total of 62.31% of the variance was explained, Factor 1 accounted for 47.85% and Factor 2 a further 14.46%. Rotation converged after 10 iterations and all questions now loaded onto a factor. Reliability analysis showed that Cronbach's Alpha increased for Factor 1 only when question 5 was removed, resulting in a value of .90. Although this would improve reliability, Cronbach's Alpha was already very high and therefore removal of this question was not deemed necessary. For Factor 2 Cronbach's Alpha would increase if question 9 was removed, with it improving to .68. It was therefore decided to remove question 9 and repeat the analysis. Q9 was "The colour has the same shape as the letter number".

All correlations were now significant, the Determinant was good (.008) as was the KMO (.89; Kaiser, 1974) and Bartlett's Test of Sphericity was highly significant (X (36) = 829.02, $p < .001$). Factor analysis therefore appeared appropriate for the data. No fixed number of factors were forced so that the data guided the structure.

Rotation converged after 10 iterations. Average communalities after extraction was .66 which was close to adequate. Two factors with eigenvalues over 1 were extracted. Factor 1 (Projector) accounted for 52.92% of the variance, and Factor 2 (Associator) a further 13.37% of variance, totalling 66.29% of variance. Although Kaisers Criterion were not met, the Scree plot confirmed a two factor solution. As two factors were obtained this suggests that colour locus is not one continuous dimension as this structure was guided by the data.

"Projector" had good very good internal reliability, as was evident in a Cronbach's alpha value of .84. Removal of Q1 would have only marginally increased α (by .006) and so this question was retained. "Associator" also had very good internal reliability $\alpha = .83$. Removing Q5 would increase α only slightly (by .07) and so this question was retained.

The final two-factor structure of the questionnaire is listed in Table 1.

3.3. Illustrated Synaesthetic Experience Questionnaire (Skelton et al., 2009)

Factor and reliability analyses

The appropriateness of completing factor analysis on the data was first determined. None of the questions followed a normal distribution, with substantial positive and negative skews being evident. Questions 3 and 5 only significantly correlated with one other question which would generally suggest they do not measure the same construct, however due to the very small number of questions they were retained. Removing them would reduce the total items to 3 which prevents more than one factor being created.

Initially, Eigenvalues over 1 were retained. The Determinant was .664, well above the required value of .00001 and Bartlett's Test of Sampling Adequacy was highly significant (X (10) = 70.204, $p < .001$) however KMO was only .439 which

Table 1
Factor loadings and reliability analysis for the R-RSPA.

Scale and items	Reliability	Eigenvalue	*M*	SD	1	2
1. Projector						
Q1. When I look at a certain letter or number, I "see" a particular colour	α = .84	4.76	2.79	1.64	.71	
Q4. It seems that the colour is on the paper where the letter/number is printed			1.96	1.36	.61	
Q6. The colour is, if it were, projected onto the letter/number			2.44	1.55	.84	
Q11. I see the synaesthetic colour very clearly in proximity of the stimulus (e.g. on top of it or behind it or above it)			2.07	1.43	.77	
Q12. When I look at a certain letter/number, the synaesthetic colour appears somewhere outside my head (such as on the paper)			1.98	1.44	.66	
2. Associator						
Q2. When I look at a certain letter/number, the accompanying colour appears only in my thoughts and **not** somewhere outside my head (such as on the paper)	α = .83	1.20	3.93	1.46		.85
Q3. When I look at a certain letter/number, the accompanying synaesthetic colour comes in my thoughts but on the paper appears only the colour in which the letter/number is printed (e.g. a black letter against a white background)			4.06	1.38		.81
Q5. The figure itself has no colour but I am aware that it is associated with a specific colour			3.53	1.49		.70
Q10. I see the colour of a letter/number only in my head			3.80	1.48		.78

is below the recommended value of .5 (Kaiser, 1974). Factor Analysis may therefore not have been most appropriate. Average communalities after extraction was only .57. Initially, two components were extracted explaining a total of 56.83% of the variance. After rotation, which converged after 7 rotations, Q3 did not load onto either factor and was therefore removed. Q3 was "You experience a coloured copy of the letters in your 'mind's eye' and black and white on the page". As Kaiser's Criterion were not met the scree plot (see Appendix B) was referred to and it supported a two factor solution. The factor analysis was therefore repeated using a forced two factor solution.

Q5 still did not correlate significantly with half the other questions. The Determinant was .693, Bartlett's was highly significant ($X(6) = 62.98$, $p < .001$) and KMO was inadequate at .44 (Kaiser, 1974). Average communalities after extraction was now .69 which is near .7 and therefore acceptable however Kaiser's Criterion were still not met. The scree plot still suggested a two factor solution. The total variance explained was high at 69.33%. Factor 1 (Projector) explained 35.43% of the variance, and Factor 2 (Associator) a further 33.91%. Therefore, the Factor Analysis showed that a single factor solution was not optimal, and colour locus includes more than one dimension (two using this questionnaire). As there were only two questions in each factor, Cronbach's Alpha could not be calculated. Spearmans's Rho Correlation was therefore used. The correlation for both the Projector and Associator factors were highly significant.

Table 2 shows the two factors and the questions that comprise them.

3.4. Correlational analyses

If localisation is a continuous dimension with a bimodal distribution then it would be expected that participants experienced one type of localisation only, which is not the case as can be seen in Fig. 1. Furthermore this continuous dimension is necessary for the coding scheme used to calculate the sub type for each participant, as the mean associator score is subtracted from the mean projector score (Rouw & Scholte, 2010; Skelton et al., 2009). This calculation is based on the theory that it is one bimodally distributed dimension and that participants should not score highly on both. As can be seen from Fig. 1 this is clearly not the case, and modification through factor analysis has not resolved this problem. Furthermore, for the RSPA it seems insufficient to consider synaesthetes undetermined if they do not clearly fit an associator or projector classification. Combined with the two factor solutions for the revised versions of both questionnaires this does suggest that there are two separate dimensions of colour locus, internal and external colour. For the R-RSPA, 7.43% responded highly to both projector and associator dimensions, and for the R-ISEQ 6.86%.

Table 2
Factor loadings and reliability analysis for the R-ISEQ.

Scale and items	Reliability	Eigenvalue	*M*	SD	1	2	*p*
1. Projector							
Q2. You "see" a specific colour > The colour has the same shape as the letter or number > The colour is not on the page, but floating in space	$r_s = .47$	1.42	2.56	1.88	.85		<.001
Q1. You "see" a specific colour > The colour has the same shape as the letter or number > The colour looks like it is on the page			3.08	2.23	.82		
2. Associator							
Q4. You experience a block of colour in your 'minds eye' and black and white on the page	$r_s = .33$	1.36	2.86	2.19		.84	<.001
Q5. You experience a sensation of knowing a letters colour			5.02	2.18		.77	

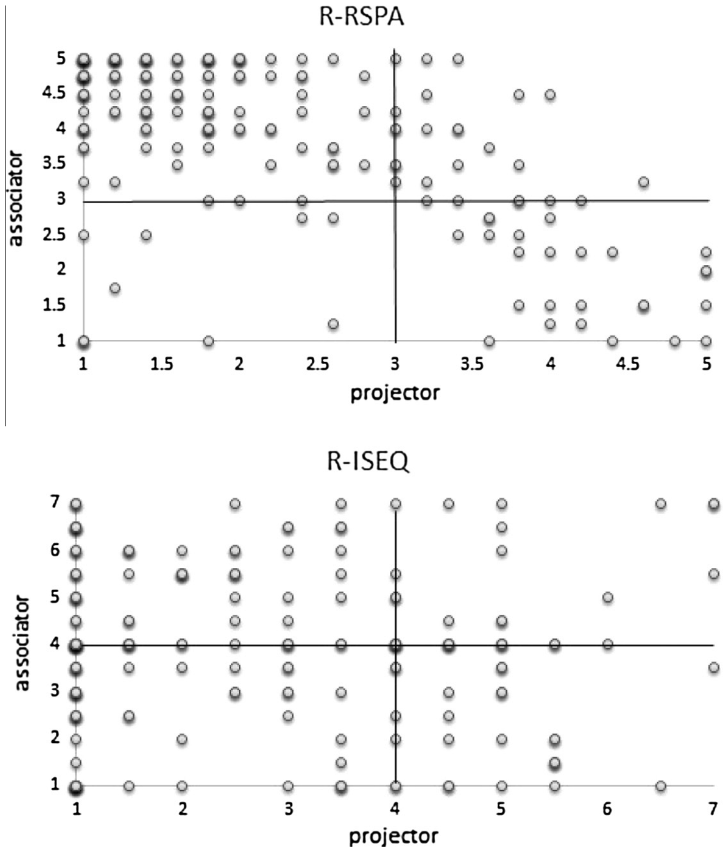

Fig. 1. Mean projector and associator scores for the revised questionnaires (R-RSPA and R-ISEQ).

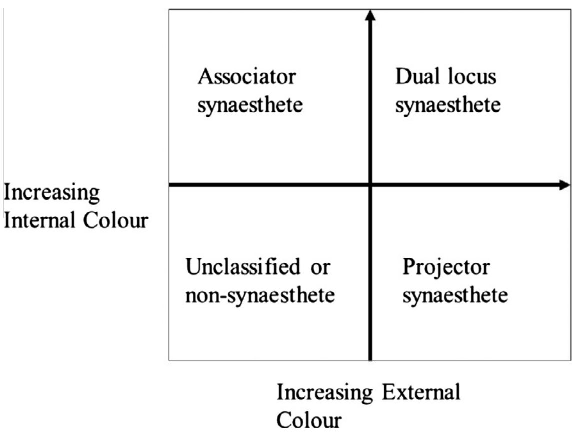

Fig. 2. Diagram of colour locus for graphemes.

Fig. 2 shows the suggested new classification system for GC synaesthete sub types which takes into consideration the two separate colour locus dimensions. Now, a synaesthete sub type can be one of three categories; projector, associator or dual locus. This allows non-synaesthetes to be isolated from dual locus synaesthetes as they would both previously obtain an "undetermined" classification on the RSPA. If a participant scores highly on both the associator and projector dimensions, when the mean associator value is subtracted from the projector value a score around zero is likely. This way, they would have a similar score to a non-synaesthete who scores low on both dimensions. Using the diagram below we can differentiate between these two groups.

3.5. Comparison against the CLaN Questionnaire (Rothen, Tsakanikos, et al., 2013)

As can be seen from Table 3, the strongest relationships between the revised questionnaires and other measurements is the Localisation dimension of the CLaN questionnaire which had significant correlations with the projector dimension of the R-ISEQ and both dimensions of the R-RSPA, providing criterion validation for the revised questionnaires. The associator dimension of the R-ISEQ only correlated significantly with the longitudinal changes of the CLaN questionnaire. Interestingly, none of the components correlated significantly with the Synaesthesia Battery consistency measurement (Eagleman et al., 2007).

As the CLaN had a question which corresponds to the dual locus category we are proposing (Q6 "I experience the synaesthetic colours in several locations at the same time (for instance, both on the screen and literally inside my head or some other combination)"), we compared answers to this question between participants who were categorised as dual locus synaesthete ($N = 13$) or not ($N = 162$). An independent samples Mann–Whitney U test revealed a significant difference ($U = 1496.00$, $p = .01$) such that dual locus participants agreed to a greater extent with Q6 of the CLaN ($M = 3.31$, $SE = 0.36$) than non dual locus ($M = 2.29$, $SE = 0.11$). The same analysis for R-ISEQ found the difference between dual locus ($N = 12$, $M = 2.75$, $SE = 0.37$) and not dual locus ($N = 163$, $M = 2.34$, $SE = 0.11$) to be non significant ($U = 1117.00$, $p = .22$).

4. Discussion

We conducted Principal Component Analysis on two questionnaires (RSPA and ISEQ) designed to measure the subjective location of colour experiences in GC synaesthetes to test the assumption that synaesthetes fall on to a single continuous dimension (with endpoints of projector and associator). A secondary aim was to determine whether all the questions that were initially included by the authors of those questionnaires (on conceptual grounds) are appropriate on statistical grounds (e.g. that a question assumed to be related to being an 'associator' is appropriately correlated with similar items). After analysis, both questionnaires had been revised and contained two factors corresponding roughly to associator and projector factors with good internal reliability and criterion validity as measured using another scale, the CLaN. In the previous versions, questions which did not correlate generally with the other questions or load highly onto either factor would have been included thus adding noise to the projector or associator value. Now that these have been removed, the mean score obtained is likely to be a more robust measure of the degree of "projector" or "associator" status. Furthermore, the classification system of subtracting the mean associator score from the mean projector score is statistically unjustified if these are two separate factors. For these reasons, using the revised questionnaires and treating the two scores as separate dimensions may provide more internally valid measures than the original questionnaires and classification systems.

For the RSPA, the distribution of all the questions violated the assumption of normality. This is not surprising considering that many questions, although using a Likert scale, are measuring responses which are categorical. If asked, "It seems that the colour is on the paper where the letter/number is printed" most people will be inclined to respond in a yes/no manner. This causes problems not just for PCA, but for any statistical analysis which requires normally distributed data. The bimodal response distribution may, however, aid in distinguishing between GC synaesthesia sub types. This issue shall remain in synaesthesia questionnaires until a more appropriate questionnaire response method is developed.

Although one question was removed, the general structure of the R-ISEQ questionnaire remained the same in terms of the question split between projectors and associators. This is unsurprising since there were only five questions in the initial questionnaire and with only two questions in each factor, reliability could only be measured through correlation. The existence of two distinct factors however goes against a single continuous dimension classification of the ISEQ.

Table 3
Spearman's Rho correlations between; the projector and associator dimensions of the R-ISEQ and R-RSPA, the four dimensions of the CLaN questionnaire and the Synaesthesia Battery (Eagleman et al., 2007) consistency measure.

	R-ISEQ Associator	R-RSPA Projector	R-RSPA Associator	Localisation	Deliberate Use	Automaticity/ Attention	Longitudinal Changes	Consistency
R-ISEQ Projector	−.04	.67***	−.39***	.54***	.15*	.24**	.01	.06
R-ISEQ Associator		−.05	.28***	−.01	−.08	.04	−.21**	−.00
R-RSPA Projector			−.51***	.67***	.20**	.33***	−.00	.05
R-RSPA Associator				−.45***	−.03	−.15*	−.01	−.02
Localisation					.35***	.38***	.04	.02
Deliberate Use						.17*	.08	−.10
Automaticity/ Attention							.21**	−.04
Longitudinal Changes								−.06

* $p < .05$.
** $p < .01$.
*** $p < .001$.

It should also be noted, that although the inclusion of such a few questions is beneficial for keeping the questionnaire brief to complete, this makes it difficult to analyse internally as a standalone questionnaire. As at least two questions have to be grouped in order for a factor to exist, starting with five questions is very restrictive. This meant that although there were issues with non-normal distributions no questions could be removed in the preliminary analysis. The very small question size also means that the full range of synaesthetic experience may not be extensively measured. As this questionnaire has been used widely in the synaesthesia literature, it was however considered important to investigate the dimension(s) underlying the projector/associator distinction.

The final R-RSPA had a two factor solution which did not support the assumption of a single continuous dimension proposed for the original questionnaire. The two factor solution however is consistent with the factor structure we obtained from the R-ISEQ, and therefore we conclude that GC synaesthesia subtype is not one continuous dimension, but two distinct dimensions. It should be noted that although two factors were found, the questions were still grouped in the same way as the original questionnaires. It is interesting that the CLaN did not find distinct projector and associator factors. This could be due to either the restricted number of associator questions that were included, or may demonstrate that the variability within GC synaesthetes is better accounted for by a more multi-dimensional questionnaire. One question from the CLaN which supports our dual locus sub type is the question "I experience the synaesthetic colours in several locations at the same time (for instance, both on the screen and literally inside my head or some other combination)" which remained in the CLaN after PCA and was significantly correlated to the projector factor of the R-ISEQ and both factors in the R-RSPA. Therefore, the dual locus phenomenology experienced by some synaesthetes in our study is validated by the CLaN. This was not allowed for in the original versions as the process of subtracting associator from projector scores would have given the misleading impression of experiencing colours 'nowhere' instead of 'everywhere'. The fourth category of synaesthete (in the lower left quadrant of Fig. 2) effectively denies being a projector or an associator. One possibility is that some of these participants are not, in fact, synaesthetes at all. A more interesting possibility is that they would agree with other kinds of statements about spatial phenomenology (e.g. experiencing them literally inside the body, or externally but not on the page). These questions were not included at all on the RSPA or ISEQ. They were included in the CLaN but may have been insufficient in number (either number of participants, or number of items, or both) to emerge as a separate factor.

The Synaesthesia Battery consistency measure was not found to correlate significantly with the projector or associator dimensions. This is interesting considering that consistency is one of the main criteria used for defining someone as a synaesthete (Auvray & Farina, submitted for publication).

We propose that there is not one continuous subtype of grapheme-colour synaesthesia, rather there are (at least) two separate dimensions. Synaesthetes could therefore be categorised (minimally) as projector, associator or dual locus synaesthete. Using this categorisation may improve analysis of differences between groups, as the previously standard system of subtracting association scores from projector scores means that synaesthetes who agree to both dimensions could be wrongly categorised, and perhaps generate noise within a projector/associator participant group.

Conflict of interest statement

This research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2015.01.013.

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