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IDEAESTHESIA: CONCEPTUAL PROCESSES ASSIGN SIMILAR COLOURS TO SIMILAR SHAPES

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Abstract

One of the main problems in understanding synaesthesia is determining whether it is a sensory or semantic phenomenon–a problem also known as the distinction between 'low-' vs. 'high-level' synaesthesia. Recently, it has been reported that in grapheme-colour synaesthesia, the colour associated to a letter is chosen by similarity to other letters. Letters of similar shapes tend to elicit similar colours. The authors explained this result by low-level cross-wiring between grapheme and colour brain areas. In the present study we show that when new graphemes are learned, they also associate synaesthetic colours based on shape- and colour similarity. Importantly, these novel associations between graphemes and colors are created within minutes, which is too rapid to be accounted for by cross-wiring. In addition, the dimensions of similarity used to create these associations were more abstract than what would be expected from elementary features processed in the grapheme area. Therefore, we conclude that the result is better explained by high-level conceptual mechanisms that guide the choices and creation of synaesthetic concurrents.

Keywords

• Grapheme-colour synaesthesia • Ideaesthesia • Multidimensional scaling • Conceptual mechanisms • Semantics

1. Introduction

Synaesthesia is a phenomenon experienced by a small proportion of individuals whereby certain stimuli, called the inducers, elicit additional perceptual experiences known as concurrents (e.g., [1]). For example, in grapheme-colour synaesthesia, the perception of an alphanumeric symbol (e.g. the letter 'A') causes a sensation of a colour (e.g. light red-brown). The authenticity of synaesthetic experiences has been confirmed by objective measurements from third-person perspectives [2-5]. Yet, a widely accepted explanation of the origin of synaesthesia is still lacking. Initially, it was thought that it was a 'low-level' phenomenon of 'crossed senses', and the evidence seemed to have supported this view. In particular, the evidence suggested that the concurrents have true perceptual quality [3,4,6]. Later, however, new evidence indicated that synaesthetic *inducers* have a semantic, rather than perceptual, nature [7-13]. These two sets of results need not contradict each other. Instead, both levels can be incorporated into a view in which a conceptual inducer associates a perceptual concurrent. This phenomenon can be described as ideaesthesia, "sensing ideas" [11].

Investigating this hypothesis requires specifying the processes that underlie the mapping of inducing concepts to sensory concurrents. Considering grapheme-colour synaesthesia, one would like to know why a particular letter has a particular concurrent colour assigned to it, and which implications this association may have on understanding the nature of the phenomenon.

This idea was recently investigated by Brang et al. [14], who reported that for letter-colour pairings, letters that have similar shapes tend to be associated with similar hues (a small positive correlation of $r = 0.082$). Importantly, Brang et al. interpreted their results as evidence that in grapheme-colour synaesthesia both concurrents and inducers operated at a low-level, (i.e., that this is a phenomenon of crossed senses). They proposed a cascaded cross tuning (CCT) model in which synaesthesia results from crosstalk of the grapheme area in the posterior temporal lobes with the neighboring colour areas in the fusiform gyrus.

However, this conclusion contradicts other evidence that suggests in grapheme-colour synaesthesia, context and therefore the interpreted meaning of the stimulus fully determines the associations of the colours [7]: An ambiguous figure that could either be interpreted as a '5' or as a 'S' will elicit one colour if it is presented in the context of digits (and hence interpreted as '5') and another colour in the context of letters (interpreted as 'S'). A number of other studies also indicated that the associated concurrents depend on the interpretation of the stimuli [8-10,12].

Therefore, the link between the similarity of shapes and the similarity of colours should also have an interpretation on the semantic level. Specifically, the process of choosing the concurrent that will be associated with the inducer may operate at the level of conceptual representations. Hence, contrary to the assertion by Brang et al. [14], this would support the notion of ideaesthesia, (i.e. concepts inducing perceptual experiences).

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To investigate this hypothesis, in the present study we first identified the dimensions by which the similarities of grapheme shapes are being judged by synaesthetes and non-synaesthetes. Secondly, we used these dimensions to create novel graphemes with varying degrees of similarity and, implementing a semantic learning task (adopted from Mroczko et al., [10]), investigated whether the subjects would be able to create novel synaesthetic associations. Novel inducer-concurrent mappings were created quickly (within minutes), ruling out explanations of synesthesia based on 'low-level' cross-wiring mechanisms, which would have required much slower perceptual learning. Instead, the evidence suggests involvement of 'high-level' semantic processes.

2. Experimental Investigation

2.1. Experiment 1

The primary purpose of this experiment was to obtain the dimensions over which non-synaesthete subjects judge the similarities between Latin graphemes. These dimensions were needed to construct novel graphemes for Experiment 2. In addition, we investigated the dimensions over which synaesthete subjects judged the similarities between colours associated to graphemes.

2.1.1. Methods

Participants: Ten self-reported grapheme-colour synaesthetes (8 female and 2 male) and ten non-synaesthete subjects (5 female and 5 male), all German speaking, participated. Synaesthetes were recruited via a web forum (www.synaesthesie.net).

Procedure: Synaesthetes made comparisons between the colours associated to all possible pairs of the 26 Latin letters (in total 325 comparisons), printed in upper case Arial font. Similarities were judged on a 9-point scale, 1 denoting "very high similarity", and 9 a "very low similarity". No instructions about the criteria for, or definitions of similarity were given to either group. Synaesthetes did not judge the similarities of letters' shapes because these judgments may have been confounded by the similarities of the associated colours, which then would have inflated the correlations. To determine the significance of the correlations between the judgements, we calculated a t-test for correlation coefficients. This test requires n - 2 degrees of freedom (df) with n - 2 being the number of independent cases used to calculate the correlation.

In this study, the number of cases was 325, (i.e. the amount of possible letter combinations). However, there are possible dependencies in the ratings, (e.g. if someone judges R as being "very similar" to B, she might feel compelled to also judge R as "very similar" to P, with the result of these two ratings being dependent on each other). The *df* would then be overestimated by taking $n - 2 = 323$, because not all 323 ratings are 'free'. To avoid a false positive result, we only assumed the independence of the 26 letters as a conservative estimate for *df*, hence $n = 26$ and $n - 2 = 24$.

2.1.2. Results and Discussion

Pairwise similarity judgments were used to analyse the structure of the space within which these ratings were distributed. Multi-dimensional scaling (MDS) of non-synaesthete judgements revealed that a three-dimensional space accounted well for shape similarity ratings (stress I = .147; stress II = .435; DAF = .978). Thus, according to Kruskal [15], the three-dimensional MDS models were good descriptions of the similarity judgments between graphemes (see Figure 1). In addition, 8 out of 10 non-synaesthetes agreed that the pooled data matched their own respective impressions of (dis-)similarities between the shapes.

Importantly, the MDS analyses of synaesthete responses produced similar results. MDS indicated a three-dimensional space of colour similarity ratings (stress I = .196; stress II = .624; the dispersion accounted for, DAF = .962), 9 out of the 10 synaesthetes agreeing with the pooled data in Figure 1.

Thus, the following three dimensions could be identified in both analyses:

Dimension 1: *round* vs. *angular*, e.g. O, C, S vs. H, M, Z;

Dimension 2: *closed* vs. *opened upwards* vs. *opened downwards*, e.g. O, D, P vs. Y, V, W vs. M, N, A;

Dimension 3: *horizontally symmetric* (or undirected) vs. *directed to the left* vs. *directed to the right*, e.g. M, O, X vs. J vs. B, R, F.

We also computed a correlation between the judgments of synaesthetes (judging colour similarity) and non-synaesthetes (judging shape similarity), which was both positive ($r = 0.35$), and significant ($p < 0.05$). This value was considerably higher than that observed by Brang et al. ($r = 0.082$; 12% vs. 2% of explained variance, respectively). One must be cautious when taking these results as evidence that the association of the colour-shape similarities is stronger than as presented by Brang and colleagues. Rather, our subjects were prompted by letters in order to judge the associated colours. Thus, one cannot exclude the possibility that this correlation also reflects the similarities between shapes, as the presence of letters may have inadvertently affected the judgments of colour similarities. Hence, in our later analyses we consider this correlation as the upper estimate of the degree to which the similarities of graphemes affect the judgments of the similarities of colours evoked by those graphemes.

2.2. Experiment 2

The grapheme-colour associations investigated by Brang et al. [14] were acquired under natural conditions during childhood. Hence, no information is available on the circumstances surrounding the formation of the synaesthetic associations, specifically the time from the first encounter with a grapheme until the emergence of its synaesthetic colour. In Experiment 2, subjects were placed in a situation where they had to create a new set of synaesthetic associations, without being directly instructed to do so. Similarly, as done by Mroczko et al. [10], new graphemes (here named 'Qsonz' ([kzonz]), were presented to the subjects. Meaning was assigned to these graphemes through a writing exercise. If in grapheme-colour synaesthesia, an inducer is associated to its concurrent by a mechanism operating instantaneously, Qsonz graphemes similar in shape should associate similar colours only after a few encounters of the new grapheme.

2.2.1. Methods

Participants: 25 grapheme-colour synaesthetes were taken from a database of synaesthetes whose synaesthesia had been confirmed

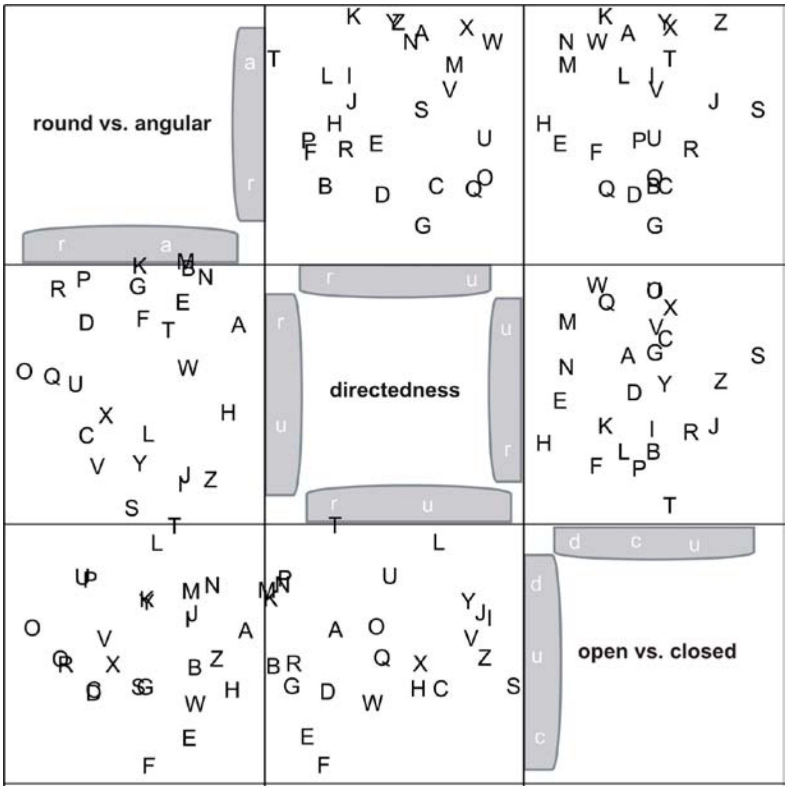

Figure 1. Three dimensions for the shapes of Latin letters. Multi-dimensional scaling (MDS) configurations for the 26 Latin letters obtained either by judgments of their shape similarity (upper-right triangle), by non-synaesthetes, or of the similarity of the associated synaesthetic colours (lower-left triangle), by synaesthetes. The 3D MDS configuration is shown by three 2D projections for each type of rating (shape and colour, respectively). For the dimension *round vs. angular* the letters cluster according to the poles 'round' (r) and 'angular' (a). For the dimension *directedness* letters arrange according to whether they are 'directed towards right' (r) or 'undirected' (u). For the dimension *open vs. close*, the letters grade from 'open upwards' (u), to 'open downwards' (d), to being 'closed' (c).

using the synaesthesia battery [16]. None of them had participated in Experiment 1. Four of these synaesthetes did not develop colour associations to the newly learned graphemes and were thus discarded from the analyses. Their results were kept only for the purpose of control to corroborate the results obtained from 16 non-synaesthete subjects. In addition, one synaesthete had mixed success assigning new colours to graphemes, having acquired faint colour experiences for only two graphemes. This subject was fully excluded from the study. Hence, the experimental group consisted of 20 synaesthetes, 19 female and one male, with a mean age of 32.7 years (with a broad range, 9 to 53 years). The youngest participant, a nine-year-old, was a synaesthete son of another participant and had fulfilled all the criteria for inclusion in the study. Six of the 20 participants in the experimental groups were self-classified as associators, and nine as projectors. The remaining five were undecided. Non-synaesthetes, 16 female and 4 male, as a group, matched the synaesthetes by age (on average 33.4 years) and education (12.3 vs. 12.1 years of school education for controls and synaesthetes, respectively). Also, one nine-year-old control participant was recruited to match our child synaesthete. All participants were naïve with respect to the hypotheses and were debriefed only after the completion of all tasks.

Stimuli: The 24 Qsonz-graphemes were constructed on the basis of the three dimensions established in Experiment 1 (all possible combinations of these dimensions were used, see Figure 2). Care was taken that the Qsonz-graphemes did not resemble Latin letters or alphanumeric symbols of other writing systems possibly familiar to our participants (i.e., Greek and Cyrillic).

To prevent the urge to pronounce graphemes and to thus form phonetic associations, the Qsonz-graphemes were said to belong to an indigene language difficult to pronounce for speakers of Indo-European languages. Also, to avoid one-to-one correspondences to the existing synaesthetic inducers (e.g. individual Latin letters or entire words), that is, to minimize transfer of their colours to the Qsonz-graphemes, each Qsonz-grapheme was given two homonymous translations. For example, one grapheme was translated as both 'to have' and 'to possess', another with 'she' and 'woman', and a third one with 'big' and 'huge'. For every Qsonz symbol, both translations were given to each participant. Thus, unlike in Mroczko et al. [10], the suggested meaning of a new grapheme was not directly related to another existing symbol (i.e. a Latin letter) but was instead associated with an entire category such as "food" or "tallness", and these concepts are usually not associated with a single symbol. Therefore, these concepts did not have their own synaesthetic colours prior to the experiment. Also, it was not possible to easily transfer the colour of, for example, one initial letter to the Qsonz-grapheme. Thus, subjects were put in a situation with the freedom to assign novel colours to those symbols. Overall, the Qsonz dictionary consisted of 9 verbs, 6 nouns, 4 personal pronouns, 2 prepositions, and 3 adjectives. The graphemes were equally dissimilar within each of these classes of words, as well as between them.

Procedure: To familiarize the subjects with the new graphemes, a procedure similar to that introduced by Mroczko et al. [10] was used. After learning the orthography of each new symbol by hand-writing it six times, participants used the graphemes in a task that required processing their meaning. They translated 15 short German sentences to Qsonz language. To direct attention towards new synaesthetic colours, the synaesthete participants were warned that the new graphemes may or may not develop synaesthetic colour associations. The familiarization procedure lasted on average 10-15 minutes.

After the training, for each Qsonz-grapheme, synaesthetes reported whether it elicited synaesthetic colours either i) at first sight, ii) during the process of familiarization with the grapheme, or iii) never during the training. Also, to verify the dimensionality of the graphemes and to test whether correlations will increase, the participants were asked to judge the similarity of colours associated with the graphemes (if any), by making all possible 276 pairwise comparisons. The difference to the method in Experiment 1 was that the option of skipping a comparison existed for graphemes to which no colour was associated.

One important variable was the ease with which synaesthetic colours were assigned to graphemes. Thus, for each synaesthete, probabilities were calculated that: a) a synaesthetic colour will be elicited already at the first presentation of a grapheme (option i above), and b) a grapheme will not at all receive a synaesthetic colour during the experimental session (option iii above).

2.2.2. Results and Discussion

Following the training, 20 synaesthete participants reported having colours associated with at least 12 symbols (median = 16 graphemes coloured). Six synaesthetes had all 24 graphemes coloured. The remaining fourteen who developed colours only for some but not all graphemes uniformly expressed the belief that the colours would eventually emerge if the use of the symbols was prolonged. For the four synaesthetes who did not associate colours to any of the Qzons-graphemes, post hoc questionnaires revealed that their forms of synaesthesia were incompatible with the requirements of the task; one person assigned colours to vocal sounds only, one had synaesthesia exclusively for vowels, and two had synaesthesia exclusively for individual letters and not for symbols comprising the meaning of a whole word. These subjects believed that no further exposure to Qsonz-graphemes could help associate colours. Results did not differ systematically between projector and associator synaesthetes (results not shown).

Not all Qsonz graphemes evoked colours with equal ease. We investigated whether the shape of a grapheme could predict the likelihood that it will be associated to a synaesthetic colour.

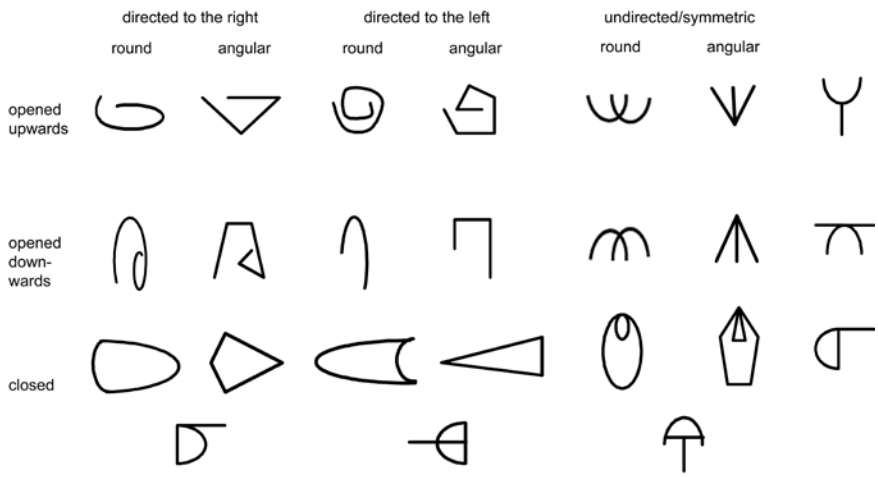

Figure 2. Qsonz Graphemes. The 24 Qsonz graphemes created according to the three dimensions of shape extracted in Experiment 1.

Across all graphemes, the probability that a grapheme would take a colour during the experiment was $Pc = .80$ and that it will elicit a colour immediately, at the first encounter, $Pci = .38$. These values were different for graphemes of simple shapes, (i.e. the round and undirected ones), than for more complex shapes, (i.e. those combining round and angular features) and the asymmetric ones (directed to the left or to the right). Simple shapes were exceptionally likely to elicit colours immediately (probabilities $Pci = .46^*$ for r and $Pci = .51^*$ for u). Also, they were more likely to take a colour at any stage during the experiment (probabilities $Pc = .84$ for r and $Pc = .88$ for u). In contrast, complex shapes had reduced likelihood of being coloured either immediately (probabilities $Pci = .30^*$ for ar and $Pci = .15^*$ for lr) or at any stage during the experiment (probabilities $Pc = .71^*$ and $Pc = .62^*$, respectively)(*: $p < .05$, Binomial test). This fast learning, after only a short exercise, indicates that a flexible conceptual process rather than cross-wiring underlies the creation of novel synaesthetic associations.

Next, we investigated whether the correlation between similarity judgments of graphemes and colours is sufficiently high to suggest that Qsonz graphemes of similar shapes were also associated with similar colours. This correlation amounted to $r = .70$ ($p < 0.0001$) and was thus much higher than in Experiment 1 (a four-fold increase in the explained variance from 12% in Experiment 1 to 49% in Experiment 2). Conjointly, these two correlations indicate that in Experiment 2, similarities in shape and colour judgments cannot be explained fully by inadvertent intrusions of shape similarities in the judgments of colour similarities. Instead, to a large degree (estimated as 49 – 12 = 37% of explained variance), this correlation reflects an amplified version of the finding reported by Brang et al. [14] (i.e. graphemes of similar shapes take similar colours). One possibility is that the remaining part of the variance can be explained by other processes that also involve semantic representations. For example, the novel graphemes may have resembled real-life objects. Then, the Qsonz-graphemes may have been associated with the colours elicited by the words describing these objects.

Finally, the three-dimensional MDS configurations accounted well for judgments of colour similarities (stress I = .161, stress II = .494 and DAF = .974) but less well for shape similarity (stress I = .275, stress II = .946, DAF = .924). Dimensionality expansion would not be justified in any of the data sets because none were better explained by four or five dimensions (results not shown). Hence, we stayed with three-dimensional representations in both cases, which are shown in Figure 3. Importantly, the spatial configurations for shape and colour similarity ratings were highly consistent with those obtained in Experiment 1, adhering to the same three dimensions, *round* *vs. angular*, *directedness*, and *open vs. closed*. This indicates that we successfully created stimuli that covered a similar dimensionality space as did the Latin letters.

3. General Discussion

In the present study we have shown that graphemes of similar shapes tend to elicit similar colours. In Experiment 2, we could demonstrate that the correlation between the two can be much higher in an artificial laboratory situation, in which no other cues for colour associations have been suggested, than in the real world where many other cues may exist [17-19]. Therefore, we can confirm the finding reported by Brang et al. [14]: graphemes of similar shapes take also similar colours.

However, in contrast to the interpretation offered by Brang et al., our findings suggest that conceptual processes, rather than low-level cross-wiring, are responsible for establishing these inducer-concurrent associations. The few minutes that our subjects had at their disposition were too short to establish both new grapheme neurons in the grapheme area and new cross-wiring connections to a colour area in the brain, as would be required by the CCT model proposed by Brang et al, [14] and others (e.g [20,21]).

Instead, the results indicate involvement of a much more flexible mechanism that takes, as input, grapheme shapes and maps them onto synaesthetic colours according to similarity relations among graphemes and colours, respectively. While theories dealing with the perception of shape traditionally stressed feature-based approaches [22], our analyses indicate that the present mechanism relies on shape dimensions that transcend basic shape features and are more generalizable (e.g. openness vs. closeness). Thus, while shapes and colours posses unquestionably a rich set of sensory features, the representations of their similarities are not necessarily perceptual in nature. Rather, the similar-shape-to-similar-colour mechanism seems to be part of a meta-process that considers the graphemes as a whole when assessing their similarities.

These conclusions are consistent with a significant amount of evidence regarding grapheme-colour synaesthesia [7,10,13] and other forms of congenital synaesthesia [12,23]. Therefore, congenital synaesthesia seems to be better understood in terms of inducing ideas that elicit perceptual concurrents by means of conceptual mechanisms, i.e. ideaesthesia.

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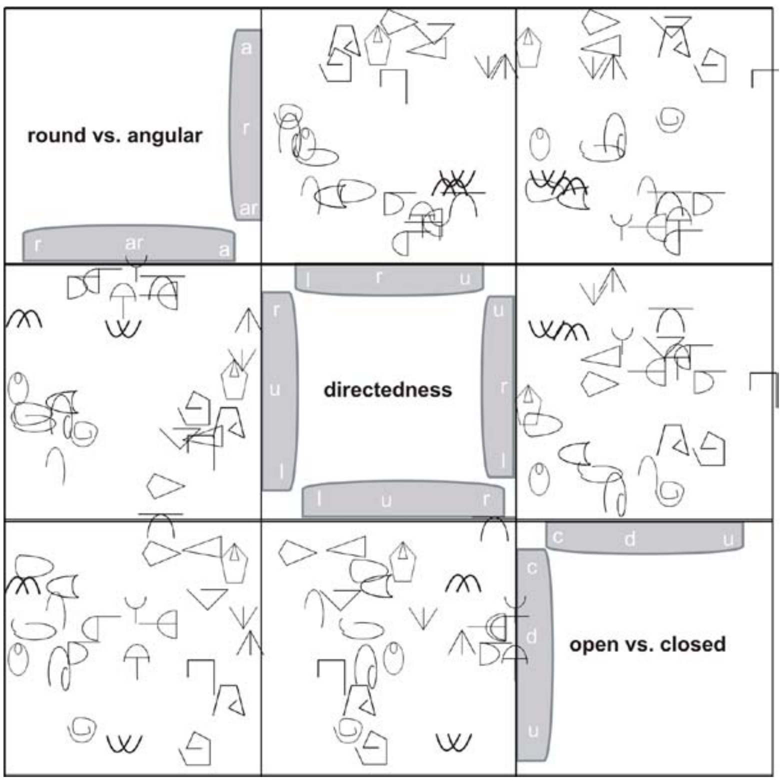

Figure 3. Three dimensions for the shapes of Qsonz graphemes. The MDS-configurations for 24 newly learned Qsonz graphemes displays the clustering of symbols according to judgments of shape similarity (as rated by non-synaesthetes) in the upper-right triangle, and according to judgments of similarity of concurrent colours (as rated by synaesthetes) in the lower-left triangle. The abbreviations for axes indices are the same as in Figure 1 except that in the dimension round vs. angular a category 'angular and round' (ar) is added, and in the dimension directedness a category 'directed towards left' (l) is added.

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