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Consistency in synesthetic experience to vowels and consonants: Five case studies

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The present study attempted to specify the actual degree of consistency in synesthetic experience in two synesthetes and three non-synesthetes. By comparing colour chip selections, and size and density ratings, to the same set of stimulus letters on separate occasions, it was found that the synesthetic subjects showed a high consistency in responding over a short (24 hours) as well as a long (one year) time span. In comparison, the non-synesthetic subjects demonstrated less consistent responding when retested after 24 hours. However, the differences between the two groups were smaller than expected. Consistency to vowels and consonants was compared, and it was found that consistency to consonants was comparable to, or even higher than, vowel consistency in all subjects.

Key words: Synesthesia; colour associations

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The existence of synesthesia—defined as an experience in one sense modality as a function of stimulation in a different modality—is well documented (Cytowic & Wood, 1982; Marks, 1975, 1978), but the degree of consistency in individual synesthetic experience has not been adequately established. Although there are reports indicating that individual synesthetic experience may be stable (e.g., Argelander, 1927), there is also evidence suggesting that the synesthetic experience of an individual may vary over time (Karwoski, Odbert, & Osgood, 1942). The main purpose of the present study was to measure the actual degree of consistency of synesthetic colour associations in two synesthetes. Although an observed consistency in only two synesthetes hardly can be argued to apply to synesthetes in general, a lack of consistency would clearly question the stability assumption. Further, a comparison group consisting of three non-synesthetic subjects was included to get an indication of differences in consistency between synesthetes and non-synesthetes.

A commonly studied form of synesthesia is coloured hearing or chromesthesia, which implies that the subject experiences colour photisms when hearing various kinds of auditory signals, such as music, instrument sounds, or even pure sinus tones (Argelander, 1927; Bleuler & Lehmann, 1881; Karwoski & Odbert, 1938; Marks, 1974, 1975; Vernon, 1930). A similar kind of synesthetic experience is linked to vowels (Argelander, 1927; Marks, 1975). Argelander (ibid.) described vowels as acoustically "cleaner" than consonants, thus making vowels preferable to consonants in studies of synesthetic experience to letters, and Marks (1978) argued that vowel sounds have a particularly great potency in arousing visual images. If vowel and consonant sounds occur together, the vowel sound is assumed to dominate in the production of synesthetic photisms (ibid.; Ginsberg, 1923). Consequently, the majority of studies on letter-colour associations have focused on synesthetic experience to vowels.

Such studies have demonstrated reliable relations between vowel pitch and colour brightness experience (Argelander, 1927; Bleuler & Lehmann, 1881; Karwoski & Odbert, 1938; Marks, 1974, 1975, 1978). High-pitched vowel sounds (e.g., /e/ and /i/) produce bright synesthetic colours, while low-pitched vowels (e.g., /o/ and /u/) produce dark synesthetic photisms. Similarly, brightness is greatest when vowels are high both in frequency and energy (Marks, 1978). Perceived "size" of the synesthetic photism is another attribute of visual synesthetic experience related to vowels (Anschütz, 1926; Bleuler & Lehmann, 1881; Dudycha & Dudycha, 1935; Karwosky & Odbert, 1938; Marks, 1975, 1978; Vernon, 1930; Zigler, 1930). Deep, low-pitched vowels (e.g., /u/, /o/, and /a/) tend to produce large synesthetic photisms, while high-pitched vowels (e.g., /i/) tend to produce smaller photisms.

The relationship between vowel sound and the hue aroused is less certain. Marks (1978) pointed out that hues aroused synesthetically from vowel presentation depend on how the vowel sounds. However, no firm relationship between the acoustic properties of vowels and specific hues aroused has been demonstrated, and hues reported to vowels seem to be at least in part idiosyncratic (Argelander, 1927; Marks, 1975, 1978).

In order to specify consistency of synesthetic colour experience beyond simple introspective report, adequate measurement of the synesthetic photism is needed. Previous studies have relied on verbal reports using a limited number of broad colour categories like "yellow", "red", "green", etc. (Argelander, 1927; Dresslar, 1903; Karwoski & Odbert, 1938; Langfeld, 1914; Marks, 1975, 1978; Myers, 1911; Reichard, Jacobson, & Werth, 1949), or on multidimensional scaling techniques restricted to a limited set of colour samples (Lehman, 1972; Wicker, 1968). This may imply that reports on consistency in synesthetic experience can be attributed to memory mechanisms. It is possible that synesthetes learn and remember colour associations to various stimuli without necessarily experiencing associations on every occasion when the relevant stimulus is present. Such a memory mechanism may erroneously serve to enhance the subjective feeling of consistency in associations. Further, it may be questioned whether a restriction of the analysis of synesthetic colour associations to vowels only is appropriate. Many synesthetes report colour associations to consonants as well as to vowels, and to numbers, names of persons, names of weekdays, etc., and informal reports from synesthetes suggest that colour associations to consonants are as vivid and consistent as associations to vowels (Colman, 1894; Dresslar, 1903; Galton, 1883; Ginsberg, 1923; Krohn, 1892; Reichard *et al.*, 1949; Svartdal & Fossland, 1988).

In the present study, a possible memory mechanism was ruled out by instructing the subject to select colour samples from a very large number of chips. Even though synesthetes often report colour photisms with highly specific attributes, and also report that a given photism may not be uniform in hue, brightness, and saturation (e.g., Ginsberg, 1923), it was assumed that a large colour sample would increase the probability of finding samples matching the actual photism. The same set of stimulus letters was presented to each subject on two separate days. After one year, the same set of stimulus letters was again presented to the two synesthetic subjects in order to measure long-term consistency. To test the assumption that vowel letters serve as particularly strong stimuli for synesthetic experience, a systematic comparison between responses to vowels and consonants was made. It was reasoned that if consonant letters produce less vivid photisms than vowels, less consistent associations to consonants should also be expected.

METHOD

Subjects

Two university students (females, aged 26 and 23 at the time of the initial study) served as synesthetic subjects. Both reported vivid synesthetic colour associations to letters, numbers, and names. Three randomly selected university students (two females and one male) served as comparison subjects. None of these subjects reported synesthetic experiences in any form when interviewed prior to the investigation. All subjects had normal colour vision.

Table 1. *Normal Norwegian pronunciation of the letter names used*

Letter	IPA
a	[a:]
b	[be:]
c	[se:]
d	[de:]
e	[e:]
f	[ɛf]
g	[ge:]
h	[ho:]
i	[i:]
j	[je:]
k	[kʰo:]
l	[ɛl]
m	[ɛm]
n	[ɛn]
o	[u:]
p	[pʰe:]
q	[kʰu:]
r	[ɛr]
s	[ɛs]
t	[tʰe]
u	[ʉ:]
v	[ve:]
w	['dɔ bɔ lt,ve:]
x	[ɛks]
y	[y:]
z	[sɛt]
æ	[æ:]
å	[o:]

Stimuli

Individual letters were presented visually printed on white cards, and the letter name was simultaneously read aloud to the subject. All letters in the Norwegian alphabet, except /ø/, were included (see Table 1). Both the sequence and the actual selection of letters were randomly determined, but each letter was presented at least once during each session.

Colour sample

The colour sample used was the Munsell Book of Color (1976 Edition), Glossy Finish Collection, with supplementary 80-hue colours. A total of 1568 chips distributed on 41 separate hue charts contained in two volumes were available for selection. Chip identification codes were always concealed.

Procedure

Each subject was tested individually in a sound attenuated room with daylight falling in from the left. Illumination conditions were roughly constant during all trials; slight differences in illumination would, if present, run counter to the consistency hypothesis and were therefore not considered crucial.

Each trial was started by presenting a card with a stimulus letter. The letter name was read aloud to the subject. The subject was then asked to select the appropriate colour chip. She/he was told to take the time needed, and could compare chips by paging through the two Munsell volumes. Removal of individual chips from their positions was not allowed. After a chip had been selected and its hue, value, and chroma scores had been recorded, the chip was randomly inserted into a new position on its appropriate hue chart, and a number of other chips on the same hue chart were also randomly repositioned. This was done to prevent chip position from being a clue in subsequent chip selections.

When interviewed before the investigation commenced, both synesthetic subjects agreed that "size" (Anschütz, 1926; Bleuler & Lehmann, 1981; Karwoski & Odbert, 1938; Marks, 1975, 1978; Vernon, 1930;

Zigler, 1930) and "density" (Marks, 1975; Wicker, 1968) were meaningful attributes of their synesthetic experience to letters. Following chip selection, the subjects therefore indicated, on a scale ranging from 1 to 11, first the "size" and then the "density" of the percept associated with the stimulus letter.

The sessions, each consisting of 50 trials, were distributed on three occasions, first on two following days (all subjects) and then on one day about a year later (the synesthetic subjects only). One synesthetic subject had her first two sessions distributed over four different days. This was necessitated by practical circumstances, but it was reasoned that this change in procedure would, if anything, make the task even harder.

Scoring

Since a chip code in the Munsell system describes a position in a three-dimensional space on the hue, value (brightness), and chroma (saturation) dimensions, scoring a chip by a single number is problematic (cf. Indow, 1974). A score on one dimension (e.g., hue) may depend on scores on the two other dimensions. For example, if a colour associated to a letter is dark or pale, a matching chip may be found on several hue charts. The hue score may therefore vary, even if the colours selected are virtually identical. Keeping this in mind, each chip selection was scored separately by hue (corresponding to the hue position in the 0–100 hue circuit), value (0–10), and chroma (0–16). Scoring of size and density was made by using the actual estimates, ranging from 1 to 11.

RESULTS AND DISCUSSION

Both synesthetic subjects found the task meaningful and had few problems in identifying colour chips and giving estimates of size and density to match most synesthetic photisms. However, both noted that several of the photisms were not uniform in hue, value, and/or chroma, and that the Munsell chips identified only were approximations as representations of these photisms. Two of the non-synesthetes found the task rather meaningless, as they had no colour associations to the stimulus letters at all. The third non-synesthetic subject found the task more meaningful, and in the course of the investigation it became evident that she had quite strong colour associations to some of the stimulus letters.

Short-term consistency

Chip selection. Consistency in chip selection may be determined simply by computing the proportion of exact matches between the two sessions. The synesthetes selected the identical chip in 28% and 10% of the cases; the corresponding figures for the three non-synesthetes were 0%, 0% and 2%. When the proportion of exact matches was assessed for each score separately, the two synesthetes demonstrated a high proportion of exact matches (48%, 54%, and 76% on the hue, chroma, and value dimensions respectively), while the three non-synesthetes matched their own scores between the days in only about 20% of the possible cases (see Figure 1). Although these match criteria are very strict and do not take into account the fact that the "same" colour can be described by different combinations of hue, value, and chroma, the synesthetes nevertheless demonstrated relatively consistent selections while the non-synesthetes showed a markedly lower consistency.

A more satisfactory measure of consistency would be one permitting a quantification of the strength of relationship while allowing for slight variations in the actual scores between the sessions. The first and second day hue, value, and chroma scores were therefore subjected to correlational analyses. Table 2 shows that selections by this measure were highly consistent for both synesthetic subjects and quite high for two of the three non-synesthetic subjects.

Correlational analyses of the hue scores may be negatively affected by the fact that hue scores depend on the value and chroma dimensions. Since dark/bright and pale colours with roughly the same properties may be found on different hue charts, chips high or low in value and low in chroma were expected to show an increased variation in hue. Consequently,

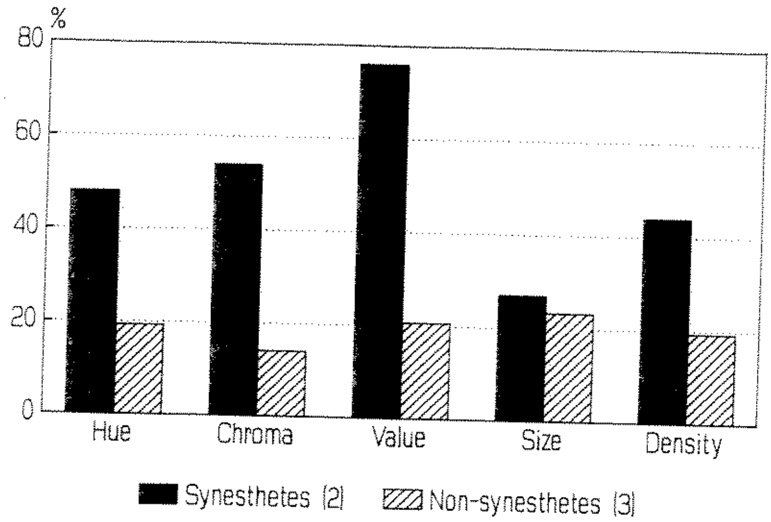

Figure 1. Mean per cent exact match between first and second sessions.

Table 2. *Pearson r, first vs. second day scores, all letters*

	Hue	Value	Chroma	Size	Density
Synesthete 1	**.71**	**.93**	**.87**	**.65**	**.85**
Synesthete 2	**.82**	**.97**	**.91**	**.68**	**.80**
Non-synesthete 1	**.57**	.77	**.81**	**.54**	.32
Non-synesthete 2	**.78**	[.08]	[−.18]	**.68**	**.54**
Non-synesthete 3	[.27]	[.12]	.32	**.81**	**.67**

Note:
$p<.01$ for coefficients in bold;
$p<.05$ for coefficients in normal;
p=n.s. for coefficients in [..]

removal of chip selections with extreme scores on value and low chroma scores from the analysis should give a better indication of hue consistency. Elimination of chips with extreme scores on value (below 2 and above 8) clearly improved consistency in hue scores for both synesthetic subjects ($r(16)=.96$ and $r(26)=.998$), but not for the comparison subjects (see Table 3). Similarly, the effect of eliminating chips with chroma scores below 3 from the analysis also increased hue consistency for the two synesthetes ($r(29)=.996$ and $r(28)=.997$), while the consistency for the non-synesthetic subjects remained relatively unchanged.

A comparison of consistency in scores to vowels and consonants indicated a high consistency for both synesthetic subjects; however, a tendency towards more stable hue scores for consonants than for vowels was observed (Table 4). The same conclusion applied to the non-synesthetic subjects, although the correlations generally were lower.

The potency of consonant letters to generate consistent synesthetic experience is further demonstrated by an inspection of the stimulus letters that generated exact chip selection matches between the two sessions. Eight of those stimulus letters turned out to be consonants; the stimulus letters were /s/, /t/, and /æ/ (synesthete 1), and /b/, /c/, /d/, /i/, /o/, /p/, /q/, /w/, and /å/ (synesthete 2). If the vowel sound dominates over the consonant sound in the production of

Table 3. *Pearson r, hue scores, first vs. second day. The two rightmost columns show the effects of removing low chroma scores from the analysis (middle column) and of removing extreme value scores from the analysis (rightmost column)*

	All scores (n)	Without low chroma (n)	Without extreme value (n)
Synesthete 1	**.71** (50)	**.996** (29)	**.96** (16)
Synesthete 2	**.82** (50)	**.997** (28)	**.997** (26)
Non-syn. 1	**.57** (50)	**.61** (35)	**.78** (34)
Non-syn. 2	**.78** (50)	**.78** (46)	**.76** (38)
Non-syn. 3	[.27] (50)	[.19] (31)	[.27] (16)

Table 4. *Consistency in vowels vs. consonants (Pearson r)*

	Hue	Value	Chroma	Size	Density
Synesthete 1					
Vowels (13)	.56	**.95**	**.72**	**.67**	**.74**
Consonants (37)	**.76**	**.90**	**.90**	**.63**	**.84**
Synesthete 2					
Vowels (13)	.60	**.99**	**.95**	.53	**.81**
Consonants (37)	**.995**	**.95**	**.91**	**.72**	**.80**
Non-synesthete 1					
Vowels (13)	**.73**	**.79**	**.83**	[.29]	[−.17]
Consonants (37)	.41	[.08]	[.19]	**.65**	**.54**
Non-synesthete 2					
Vowels (13)	**.73**	[.36]	[.37]	**.77**	[.37]
Consonants (37)	**.82**	[−.26]	[−.24]	**.65**	**.57**
Non-synesthete 3					
Vowels (13)	[.06]	[−.32]	[.40]	**.69**	[.45]
Consonants (37)	.33	[.24]	[.29]	**.87**	**.75**

synesthetic experience (cf. Marks, 1978), colour association to a given consonant should be determined by the vowel sound in that consonant name. Seven of the consonant names in this sample have the vowel /e/ either before or after the consonant sound, but only three of them (/d/, /s/, and /w/) aroused a hue comparable to the hue associated with /e/. The consonant /q/ has the vowel sound /u/ after the consonant sound, and the hue aroused to /q/ was identical to the hue associated to /u/.

A similar analysis was carried out for other consonants with /e/ in the consonant name. In fifteen out of a total of 19 Norwegian consonant names the consonant sound is either preceded or followed by the vowel /e/. However, the present data revealed no systematic relationship between colour selections to /e/ and to consonants with the vowel sound /e/ either before or after the consonant sound.

Thus, consonants seemed to be as potent as vowels in arousing consistent synesthetic associations, and the vowel sound in the consonant name did not determine the hue aroused by the consonant. A similar conclusion applies to the value and chroma dimensions. These data therefore question the assumption that vowels dominate over consonants in the production of synesthetic associations (cf. Argelander, 1927; Ginsberg, 1923; Marks, 1978).

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Size and Density. None of the subjects reported associations of synesthetic colour experience to spatial properties or objects. Nevertheless, a high consistency in estimates of size and density was observed (see Table 2). In contrast to the chip measures, a relatively small group difference emerged in the size and density estimates. Consistency in size and density estimates to consonants tended to be at least as high as to vowels (see Table 4).

Apart from the fact that "size" and "density" seemed to be subjectively meaningful attributes of synesthetic photisms for the two synesthetic subjects, the meaning of these two concepts is somewhat obscure, and estimates of size and density were generally less consistent than the other three measures. The *size* estimates did not correlate significantly with any other measure obtained in this study. Further, the assumption that deep, low-pitched vowels (/u/, /o/, and /a/) generate large synesthetic photisms and high-pitched vowels (/e/ and /i/) generate smaller photisms (Anschütz, 1926; Bleuler & Lehmann, 1881; Karwosky & Odbert, 1938; Marks, 1975, 1978; Vernon, 1930; Zigler, 1930) was not supported by the present data.

One subject (synesthete 1) seemed to associate *density* with value (the correlation coefficient between density scores and value scores was in the range of .70–.77). However, a similar relationship was not observed in the second synesthete (r=.09–.23). This warrants the conclusion that even if the density estimates are consistent and thus may be subjectively meaningful in the description of synesthetic photisms, the meaning of this concept may be idiosyncratic.

Long-term consistency

Even if short-time consistency is demonstrated, there is still a possibility that synesthetic experience may change over longer time spans. A few reports (e.g., Devereux, 1966; Dresslar, 1903; Ginsberg, 1923; Karwoski & Odbert, 1938; Langfeld, 1914) indicate that synesthetic percepts to specific stimuli are stable over long time intervals. However, due to the methodological problems noted, this question must still be considered open.

Scores from the second day of the first test were compared with scores obtained from a retest performed about one year later. Only the two synesthetes participated in this retest. A check for exact match in chip selection (i.e., an exact correspondence in all three chip selection scores) revealed a correspondence of 18% and 14% between the sessions (the corresponding match percentages obtained in the 24 hours test-retest were 28 and 10). Further, as is evident from Table 5, correlational analyses revealed a very high consistency in chip selection scores, and in the size and density estimates over the one year lap. These data therefore strongly support the assumption that synesthetic experience is stable over long time spans.

Table 5. *Consistency over one year (Pearson r)*

	Hue	Value	Chroma	Size	Density
Synesthete 1	**.83**	**.88**	**.76**	**.68**	**.71**
Synesthete 2	**.99**	**.96**	**.90**	**.65**	**.61**

CONCLUSIONS

The data presented clearly show that consistency in synesthetic experience, as measured by colour chip selections and estimates of the size and density of the synesthetic percepts, was very high and stable in the two synesthetic subjects. Two additional conclusions are warranted. First, the data somewhat surprisingly showed that consistency to consonant letters was as high as to vowel letters. This may indicate that the role of vowel sounds in synesthetic experience may be less significant than has often been assumed. Second, although a group difference on four of the five consistency measures was evident, the non-synesthetic subjects participating in this investigation demonstrated a consistency that clearly exceeded chance levels. This supports the assumption that synesthetic associations are orderly even though they are not subjectively vivid (cf. Marks, 1974, 1978), and underscores the difficulty involved in classifying a person as either "synesthetic" or "non-synesthetic". Clearly, synesthetic associations may be subjectively more or less salient, but subjective saliency is not the sole criterion for the presence of reliable cross-modal associations.

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