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# Synaesthesia: The prevalence of atypical cross-modal experiences

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**Abstract.** Sensory and cognitive mechanisms allow stimuli to be perceived with properties relating to sight, sound, touch, etc, and ensure, for example, that visual properties are perceived as visual experiences, rather than sounds, tastes, smells, etc. Theories of normal development can be informed by cases where this modularity breaks down, in a condition known as *synaesthesia*. Conventional wisdom has held that this occurs extremely rarely (0.05% of births) and affects women more than men. Here we present the first test of synaesthesia prevalence with sampling that does not rely on self-referral, and which uses objective tests to establish genuineness. We show that (a) the prevalence of synaesthesia is 88 times higher than previously assumed, (b) the most common variant is coloured days, (c) the most studied variant (grapheme – colour synaesthesia)—previously believed most common—is prevalent at 1%, and (d) there is no strong asymmetry in the distribution of synaesthesia across the sexes. Hence, we suggest that female biases reported earlier likely arose from (or were exaggerated by) sex differences in self-disclosure.

## 1 Introduction

Synaesthesia is a familial condition in which ordinary activities trigger extraordinary experiences. For example, colours may be perceived from hearing sounds (Marks 1975; Ward et al 2006) or shapes experienced from tastes (Cytowic 1993). These sensations can be experienced either externally (eg as colours superimposed onto objects in the world) or as strong and overwhelming impressions in the mind's eye (and this corresponds to 'projector' and 'associator' synaesthesia, respectively; Dixon et al 2004). Synaesthesia can cause a direct crossing of the senses, or can be mediated by the effects of higher-level cognitive processing on sensory mechanisms. For instance, printed or spoken words can induce a sensation of taste in the mouth (lexical – gustatory synaesthesia—Ward and Simner 2003) or give an impression of colour (lexical – chromatic synaesthesia—Baron-Cohen et al 1987). Studies in brain imaging (Hubbard et al 2005; Nunn et al 2002) and of inheritance patterns (Bailey and Johnson 1997; Baron-Cohen 1996; Ward and Simner 2005) illustrate the genuineness of the condition and suggest that genetic mutation may cause the development of, or a failure to prune, atypical projections between otherwise unassociated regions. Hypotheses involving pruning (eg Baron-Cohen 1996; Maurer 1997) suggest that synaesthesia may be experienced by all neonates, but then lost by most people during normal processes of cell death (apoptosis). Synaesthetes, however, may retain these pathways, either completely or partially, as a result of some genetic predisposition. Genetic accounts have been strengthened by claims that synaesthesia runs in families, with an apparent female bias suggesting a possible X-linked dominant inheritance (Baron-Cohen et al 1996; Smilek et al 2002b). Indeed, the extent of this female bias in some studies (eg 6 : 1; Baron-Cohen et al 1996) has led researchers to suggest that the trait may be associated with male lethality in utero (Bailey and Johnson 1997; Baron-Cohen et al 1996). Additional support for this hypothesis came from early claims that synaesthetes' families may

contain fewer women than men (eg Baron-Cohen et al 1996; but see Ward and Simner 2005). Nonetheless, any accurate account of the inheritance of synaesthesia must rely on an exact assessment of its prevalence in the population and across the sexes, but neither quantity has been clearly established.

Estimates of the prevalence of synaesthesia have diverged widely. To some extent, this variation may have arisen owing to differences in definitional criteria, and we will return to this issue below. Additionally, variation may arise simply from a focus on different subtypes from one study to the next. However, even in studies that purport to provide the prevalence of all forms, estimates range from 1 in 4 (Calkins 1895; Domino 1989; Uhlich 1957), to 1 in 10 (Rose 1909), 1 in 20 (Galton 1883), 1 in 200 (Ramachandran and Hubbard 2001a), 1 in 2000 (Baron-Cohen et al 1996), and 1 in 25 000 – 100 000 (Cytowic 1993, 1997). Similarly, estimates of an apparent female bias have ranged from 2 : 1 (Ward and Simner 2005) to 6 : 1 (Baron-Cohen et al 1996; Rich et al 2005). The most commonly cited study (Baron-Cohen et al 1996) shows a prevalence of "at least 1 in 2000" with a female : male ratio of 5.5 : 1, and the most recent investigation (Rich et al, 2005) supports this with a prevalence of 0.024% and a female bias of 6.2 : 1. Both these studies based their estimates on the number of respondents to newspaper advertisements, together with those newspapers' circulation figures. Synaesthetes' reports were shown to be significantly more consistent over time than those of control participants, which is taken as the behavioural 'gold standard' for objective evidence of genuineness (Baron-Cohen et al 1996; Rich et al 2005; Ward and Simner 2003, 2005; Ward et al 2005). However, these studies relied on self-referral and so no conclusions can be drawn about non-responders, except the very conservative claim that they were not synaesthetes. Although earlier studies avoided the problems of self-referral by individually questioning every member of their participant pool, they established prevalence only subjectively (at 6.7% – 23.0%: Calkins 1895; Domino 1989; Rose 1909; Uhlich 1957). Hence, one set of studies tends towards a conservative estimate and the others towards a liberal one. Our study addresses these shortcomings by individually assessing a large number of people ($n = 1690$) and verifying their reports with objective tests of genuineness (ie consistency over time).

We tested two samples: one from the population of Edinburgh and Glasgow Universities ($n = 500$; female = 327, male = 173) and one from visitors to London's Science Museum ($n = 1190$; female = 582, male = 608; including 161 children aged 6 – 11 years). The University study tested for all known types of synaesthesia, while the Museum study tested only for the grapheme – colour variant, in which the experience of colour is triggered by letters and/or numerals (Ramachandran and Hubbard 2001a; Rich and Mattingley 2002; Simner et al 2006; Ward et al 2005). By showing equivalent rates of grapheme – colour synaesthesia across populations, we can extend our (broader) University study to the (larger) Museum sample. Our studies are described below.

## 2 Experimental procedures

### 2.1 *The University study*

The participants ($n = 500$) were opportunistically recruited from the communities of Edinburgh and Glasgow Universities. Each was given a spoken and written description of synaesthesia of the type used in the opening paragraphs to this paper, and these descriptions were accompanied by detailed examples. Examples were also provided of what synaesthesia is not (eg metaphorical association, such as 'being angry' = 'seeing red'). Participants were then prompted to indicate any variant of the condition they thought they may have. They did so by drawing lines on a questionnaire between a list of 'triggers' (letters, English words, foreign words, people's names, addresses/places, numerals, days, months, voices, pains/touches, movements/postures, music, noises, smells, tastes, colours, shapes/patterns, emotions) and a list of 'experiences' (colours,

shapes/patterns, tastes, smells, pains/touches, noises, flashes, music, movements). For example, participants who thought they may have music–colour synaesthesia would draw a line between music under the heading 'triggers' and colour under 'experiences'. Participants were also free to add their own item to either list, or to modify an existing item. (For example, participants RS, ES, and KL modified the trigger *people's names* to *people*, thereby indicating that their proposed synaesthesias were triggered by the notion of a person, rather than by that person's name.) The questionnaire also asked whether such experiences could be traced to a known event (eg recreational drug use) and whether the participant suffered from migraines, epilepsy, or any other known neurological condition.

Of the participants, 120 provided some type of affirmative response when asked to indicate any variant of synaesthesia. For conservativeness, we removed all participants whose atypical experiences could have been caused by medical conditions (eg epilepsy, migraines), medical treatment (eg for a brain tumour), or by recreational drug use. For ethical reasons, we also removed participants reporting variants triggered by, or inducing sensations of pain (eg pain–shape). Finally, we excluded any instance triggered by emotional states (eg emotion–taste), since we doubted our ability to replicate an identical state across two testing sessions. The remaining participants were given a set of stimuli according to the synaesthesia(s) they had reported. These items, and their reported synaesthesias, were: 26 letters (grapheme/letter–colour), numerals 0–9 (grapheme/number–colour), seven days (day–colour), 12 months (month–colour), 80 words (word–colour), 25 foodstuffs (eg liquorice: taste–shape; taste–colour), 20 proper names (eg *David*: name–colour), 20 personal associates (eg *mother*: people–smell; people–colour), 40 smells from a smell-identification kit (smell–colour) and 70 tones (music–colour). For all stimuli other than the music–colour materials (see below), potential synaesthetes wrote their associated percept for each item, or for taste–shape synaesthesia, selected one of 23 shapes (Cytowic 1993; Cytowic and Wood 1982) whose numbering reflected a continuum, from cones to pyramids to cubes, etc. Groups of non-synaesthetic controls ($n = 6–40$; see table 1) free-associated percepts to the same stimuli, and both potential synaesthetes and controls were given a surprise retest after a mean of 6.0 months (SD = 3.1 months) or 2 weeks respectively. Hence we stacked the deck against our potential synaesthetes (Baron-Cohen et al 1993, 1996; Ward and Simner 2003; Ward et al 2005) but counted only those scoring significantly higher than controls. In the case of taste–shape synaesthesia, we counted only those whose responses significantly correlated across the two test sessions, compared to controls, for whom there was no significant correlation despite the considerably shorter time interval.

For music–colour synaesthesia, we adopted established methodology and materials (Ward et al 2006) in which test and retest occur once within a single session, and again after a number of months. Participants selected a colour association for each of 70 sound stimuli, comprising 40 single notes and 30 dyads at a range of pitches and timbres (see Ward et al 2006, for details). Each sound was played for 3 s at 65 dB over headphones, in a randomised order. Participants selected a colour for each sound by moving a cross-hair cursor over the standard 'Windows API Choose Color' dialog box, which was summoned after each sound by the Visual Basic routine controlling the test. Each colour selection was converted to a single RGB (red, green, blue) vector with values ranging from 0 to 255 (where 0, 0, 0, is black and 255, 255, 255 is white). After the 70th trial, participants completed an immediate surprise retest, in which the order of items was re-randomised. Potential synaesthetes were then recalled after a delayed time interval (mean = 6.6 months; SD = 0.2 months) to repeat the retest procedure. Non-synaesthete control participants ($n = 10$; from Ward et al 2006) performed the same task, but their delayed retest occurred after only 2–3 months. Consistency was measured quantitatively as the mean overall difference in RGB values between test and

**Table 1.** Consistency in the University study. Columns 2–8 and 10 show significance for $Z$ test comparisons with non-synaesthete controls (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; $^{ns}p > 0.05$). Scores indicate percent consistency (columns 2–8), or the mean discrepancy in RGB values (column 10, where lower values indicate higher consistency). Column 9 shows Spearman correlation $\rho$s for taste–shape testing.

| Participants | Letter–colour | Number–colour | Month–colour | Day–colour | Word–colour | People–colour | Person–smell | Taste–shape | Music–colour |
|---|---|---|---|---|---|---|---|---|---|
| Controls | 36 ($n = 40$) | 35 ($n = 40$) | 44 ($n = 40$) | 34 ($n = 40$) | 43 ($n = 28$) | 34 ($n = 12$) | 33 ($n = 11$) | $\rho = 0.17^{ns}$ ($n = 6$) | 150.2 ($n = 10$) |
| LM | 100*** | | | | | | | | |
| PT | | 90** | | | | | | | |
| HJ | | | 92** | | | | | | |
| PF; RH; PM; RTH; ZH | | | | 100** | | | | | |
| BA; RP | | | | 86* | | | | | |
| RS | | | | | | 100*** | | | |
| ES | | | | | | 90*** | | | |
| KL | | | | | | | 90** | | |
| RF | 100*** | 100** | 100*** | 100** | 100*** | | | | |
| ST | 92*** | 100** | 83* | 100** | 90*** | | | | |
| CH | 96*** | 100** | 100*** | 100** | | | | | |
| AB | 92*** | 90** | 100*** | | | | | | |
| RM | 81** | 100** | | 100** | | | | | |
| AP | 96*** | 100** | | 100** | | | | $\rho = 0.45$* | |
| MW | 73** | 90** | | 86* | | | | | |
| JH | 77** | | | 86* | | | | | |
| JB | | | | | | | | | 95.0* |

retest, averaged across the two retest intervals (immediate and delayed). In this, lower mean difference scores represent greater consistency, and synaesthetes were identified as those scoring significantly lower than controls.

2.2 *The Museum study*

We recruited 1190 English-speaking visitors to London's Science Museum in June–August 2004, as part of its 'Live Science' initiative. A computerised test individually presented 36 graphemes (a–z; 0–9) in a random order, with each presentation accompanied by a palette of 13 colours (black, dark blue, brown, dark green, grey, pink, purple, orange, red, white, light blue, light green, and yellow). The arrangement of these colours was randomised on every trial, and participants were required to select (with a computer mouse) the 'best' colour for each grapheme, and to avoid choosing the same colour repeatedly. Participants then performed an immediate surprise retest, in which the order of graphemes was re-randomised. Next, participants aged 12 and above ($n = 1029$) rated six statements in a questionnaire about their experiences. These statements were:

1. When performing the experiment, I felt that I knew for certain what the colour for a letter or number should be.
2. When performing the experiment, I felt as if I was guessing what the colour for a letter or number should be.
3. Whenever I see or think about letters or numbers (printed black on white), I automatically experience the letter or number as having another colour (eg red).
4. Whenever I see or think about letters or numbers (printed black on white), I would never naturally experience the letter or number as having another colour (eg red).
5. Letters and numbers always evoke very precise colours (other than the colour they are printed in) and there were not enough colours on screen for me to choose from.

6. I have always associated the same particular colours with letters and numbers, and they never seem to change.

Responses were given on a 6-point Likert scale from "strongly disagree" to "strongly agree", and were coded 0 to 5. [In order that high scores should consistently reflect typically synaesthetic responses, the highest score (5) was assigned to "strongly agree" for questions 1, 3, 5, and 6; and to "strongly disagree" for questions 2 and 4.] Synaesthetes were identified as those scoring within a typically synaesthetic range, on both consistency and questionnaire for adults, and on the former alone for children. These ranges were established with reference to a group of known synaesthetes ($n = 20$), whose grapheme–colour associations had previously been shown to be significantly reliable over many months (mean = 5.4; SD = 4.1) compared to 40 non-synaesthete controls (means = 86.5% and 36.9%, respectively; $t_{58} = 13.07$, $p < 0.001$). Our previously identified synaesthetes completed both the consistency test and questionnaire, and we set our synaesthetic range as two standard deviations from their mean in each test (28.7 and 26.4 respectively; SDs = 4.65 and 4.64, respectively).

## 3 Experimental results

In the University study we tested 500 participants (327 female, 173 male) and identified 22 synaesthetes (15 female, 7 male), giving a prevalence of 4.4%, and a female : male ratio of 1.1 : 1, which shows no significant sex bias ($\chi^2_1 = 0.08$, ns). They exhibited 9 different manifestations, with 8 synaesthetes showing more than one variant (see table 1). Within the University sample, the prevalence of grapheme–colour synaesthesia was 1.4% (where, for the purpose of our cross-population comparison, this was defined as experiencing colours for both letters *and* numerals).

In the Museum study we tested 1190 participants (582 female, 608 male) and identified 13 grapheme–colour synaesthetes (6 female, 7 male) giving a prevalence of 1.1%, and a female : male ratio of 0.9 : 1 ($\chi^2_1 = 0.04$, ns). This group comprised 11 adults (prevalence = 1.1%; 6 female, 5 male) and 2 children (prevalence = 1.2%; both male). Figures 1 and 2 show the frequency distribution for participants' scores in consistency and questionnaire respectively, and indicate the lower limits required to satisfy the criteria of synaesthesia.

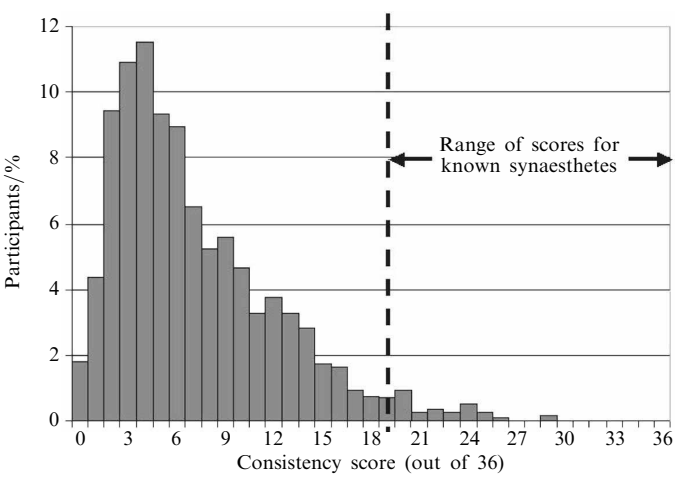


**Figure 1.** Distribution of consistency scores (out of 36; mean = 7.08, SD = 5.0) for 1165 participants in the Museum study. (25 participants chose black for every grapheme and were excluded from the consistency analysis, but counted as non-synaesthetes for the purposes of estimating prevalence.) Range satisfying the criterion for synaesthesia (2 SDs from mean for previously verified synaesthetes) is as shown.

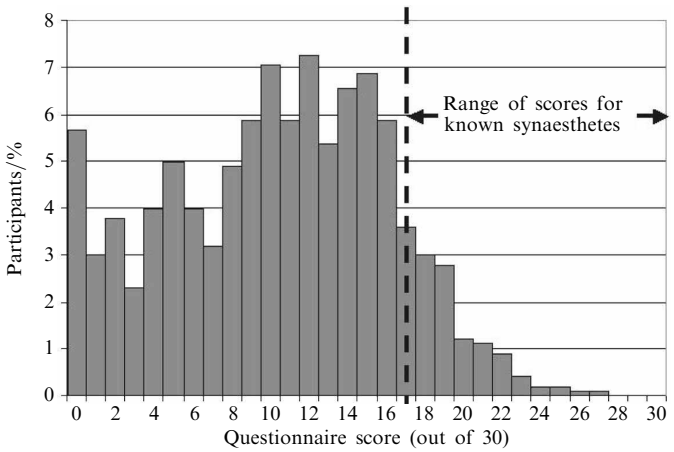


**Figure 2.** Distribution of questionnaire scores (out of 30; mean = 10.4, SD = 5.7) for 1029 participants in the Museum study aged 12 and above. Range satisfying the criterion for synaesthesia (2 SDs from mean for control synaesthetes) is as shown.

Individuals who scored within the synaesthetic range on consistency were more likely to report synaesthesia in the questionnaire, compared to individuals who did not ($\chi^2_1 = 7.46$, $p < 0.01$). This suggests our two measures are related and that our results do not reflect coincidental sampling from the upper tails of two different populations. Of the tested participants, 125 claimed to have associations between graphemes and colours but did not score highly on the objective test. These participants appeared simply to be more suggestible than the remainder of the sample, in that they were more likely to agree with questionnaire statements, even if contradictory (eg that they always experience colours, and that they never experience them; $\chi^2_1 = 10.9$, $p < 0.001$). Conversely, a small number of participants ($n = 28$) scored highly on the objective test but claimed not to have synaesthesia, and were conservatively classed as non-synaesthetes. These participants tended to use a coding strategy not reminiscent of genuine synaesthetic reports (eg 60% classed *o* as orange, compared to the more usual white/black—Day 2005; Rich et al 2005; Simner et al 2005) and were more likely to generate colours based on initial letters (eg o = orange; b = blue—Simner et al 2005) than either the Museum-recruited synaesthetes ($t_{39} = 2.71$, $p < 0.05$) or the previously established synaesthetes ($t_{46} = 7.17$, $p < 0.001$).

## 4 Conclusions

Our prevalence for synaesthesia lies midway between estimates based on self-referral (Baron-Cohen et al 1996; Rich et al 2005) and those based on subjective assessments alone (Calkins 1895; Domino 1989; Rose 1909; Uhlich 1957). We consider our calculation to be the most reliable to date, given our sampling methods, objective tests, and the converging evidence from two populations and two testing methodologies. Our study reveals a figure that is far higher than the most widely cited previous estimate (Baron-Cohen et al 1996) although this is marginally enhanced by the fact that this earlier work excluded participants ($n = 2$) reporting day–colour synaesthesia only. In our University sample, 7 synaesthetes showed this manifestation alone (and without whom our prevalence falls to 3.0%). However, current definitions of synaesthesia fit well with the inclusion of coloured days (eg Sagiv 2005; Tyler 2005; Ward et al 2005) and our data provide independent evidence for this. Hence, synaesthetes who have other forms of synaesthesia (eg taste–shape) are significantly more likely to also have coloured days, compared to people who do not ($\chi^2_1 = 109.3$, $p < 0.001$). Of the University sample, 14 synaesthetes (2.8%) exhibited day–colour synaesthesia, making

it the most common overall, and constituting at least one manifestation in 64% of synaesthetes. Grapheme–colour synaesthesia, which had been assumed most common (Day 2005; Ward et al 2005), was found in only 45% of synaesthetes (even where this is defined as experiencing colours for letters and/or numerals). We point out that although our questionnaire and testing methods allowed us to potentially verify 128 possible variants (ie combining 18 triggers and 9 experiences, but excluding those involving pain or emotional states), we found only 9 different manifestations, representing just 7% of the possible target-space. In addition, the vast majority of these had colour as the synaesthetic concurrent (ie 77% of the 9 different variants, and 95% of all instances found).

The close rate of synaesthesia across the sexes has important theoretical implications. First, our findings refute the widely held belief that synaesthesia is necessarily associated with a strong female bias (Baron-Cohen et al 1996; Rich et al 2005; Rich and Mattingley 2002; Ward and Simner 2005). This had been taken as evidence of an X-linked dominant mode of inheritance, possibly with lethality in males (Bailey and Johnson 1997; Baron-Cohen et al 1996). There was no suggestion of an extreme female dominance in our random sample, which suggests that previous 6 : 1 biases may have arisen as a reporting confound. Hence, as in other areas of self-referral (Dindia and Allen 1992), male synaesthetes may simply be less likely to come forward to report their atypical experiences. The potential for skewed prevalence in self-referred samples has been illustrated by another recent study (Ward and Simner 2005) in which an initial female : male ratio of 4 : 1 within a self-referred sample of synaesthetes was reduced to 2 : 1 when other family members were canvassed. Indeed, this 2 : 1 ratio may yet be an overestimate, since families with a lone synaesthete may be less likely to come to the attention of researchers if that synaesthete is male (and indeed, the make-up of families in this previous study supports this hypothesis).

Since we assume that any 6 : 1 predominance of females within the synaesthetic population should have shown itself (even if only very marginally) in our study, we are relatively confident that there is no increased likelihood of death in utero for males who inherit synaesthesia. However, the absence of a female bias might also undermine previous arguments for X-linked dominant inheritance, although care should be taken on this latter point. First, we found a numerical tendency (in our broad, University, study) for more female synaesthetes than male. Although this was non-significant, the small numbers of synaesthetes found in our survey raises questions about the sensitivity of our statistical tests. In addition, previous proposals of X-mode dominance in synaesthesia have been supported by claims that there is an apparent absence of father-to-son transmission. Although a small number of (uncorroborated) reports do exist in the historical literature (Jordan 1917; Laignel-Lavastine 1901), it is difficult to ensure that the trait was not present in both paternal and maternal lines (Ward and Simner 2005). What remains clear is that father-to-son instances are extremely hard to find (suggesting that they may, indeed, be absent), and this adds support for the X-linked hypothesis.

We have shown the prevalence of synaesthesia to be almost two orders of magnitude greater than commonly assumed, although this remains lower than within the families of synaesthetes (approximately 16%; Ward and Simner 2005). Hence, synaesthesia does appear to have a genetic component, and this raises questions about the function of any putative 'synaesthesia gene(s)'. It is conceivable that some small amount of failed segregation may carry particular advantages. For example, secondary synaesthetic attributes may enhance perceptual acuity—as in 'visual pop-out' effects (Palmeri et al 2002; Ramachandran and Hubbard 2001b)—and additional research suggests that synaesthetes may also have superior memories (Smilek et al 2002a). Such advantages make it conceivable that synaesthesia has been selected for by evolutionary pressures

(Ramachandran and Hubbard 2001a), and the high prevalence we find here adds weight to this hypothesis. Alternatively, synaesthesia may be an exaggerated version of some other beneficial trait (eg cross-modal perception) that is common to us all, and possibly to other animals.

We point out that our studies have limitations that reflect the pragmatic constraints of testing large samples of individuals. It is important for us to acknowledge these limitations in order to examine what effects, if any, they may have had on the results we report. Both studies here reflect opportunistic, rather than strictly random sampling across all demographics. However, given that synaesthesia is not believed to be disproportionately prominent within the age-group of the average university student, and given also that our Museum study tested a wide range of ages, it is unlikely that our results will have been strongly biased, at least with respect to the age of our participants. It is, of course, possible that we sampled in locations that attract a disproportionate number of synaesthetes (ie that a synaesthete is more likely to attend university or visit a science museum). In any case, however, it is unlikely that such a bias would be strong enough to account for the extent of our findings. In other words, assuming instead the most widely cited previous estimate of 1 in 2000 (Baron-Cohen et al 1996), we would have to conclude that synaesthetes are 88 times more likely to visit a science museum and 88 times more likely to become a student at a Scottish university. Such proposals are not only theoretically unmotivated, but also—in our opinion—unlikely. In summary then, although the current (and previous) sampling methods have their weaknesses, we believe that avoiding the motivational confound from self-referred samples will likely have provided a more reliable prevalence estimate.

One might suggest that our studies may provide an overestimate of the prevalence of synaesthesia because our methods could be susceptible to false positives. In some cases, synaesthetes were tested with fewer stimuli than in previous tests (eg $n = 7$ for University participants reporting coloured days) and in the Museum sample, the retest interval was shorter than in other studies (eg Baron-Cohen et al 1996; Ward and Simner 2003). We point out that, although we were limited by the number of items in any given testing category (eg 7 days, 12 months), the crucial fact is that our lists were equally sized for both synaesthetes and controls, and that synaesthetes perform significantly better (even considering the considerably longer time interval). Additionally, the high consistency scores of our synaesthetes were always accompanied by phenomenological reports of conscious perceptual experiences, and these were additionally verified with quantitative measures in the Museum study. Moreover, we found independent traits to distinguish synaesthetes and controls in the Museum study, such as the tendency for synaesthetes to choose o as white, but for non-synaesthetes to choose orange (Day 2005; Rich et al 2005; Simner et al, in press). Finally, it was our policy to always err on the side of caution. We removed all participants whose atypical experiences could have been caused by medical conditions (eg epilepsy, migraines), medical treatment (eg for a brain tumour) or by recreational drug use. For ethical reasons we were unable to test variants triggered by, or inducing, sensations of pain (eg pain – shape), and we also excluded any instance triggered by emotional states (eg emotion – taste). Finally, we discounted a number of additional instances which may yet constitute synaesthesia, and these are described below.

In delimiting our University study, we excluded a number of atypical reports, which may nonetheless represent additional manifestations of the condition. For example, participant AP, who experiences coloured days, numbers, and letters, and shapes for tastes, also reported that letters and numbers are seen in particular spatial orientations (*number lines*) and have specific gender and personality traits (personifications; eg *m* and *n* are garrulous women, *t* is a protective male). Other participants reported similar phenomena, and these reports have been described in the historical literature (Calkins

1895; Flournoy 1893). We excluded such reports because they had yet to be included in any modern typologies of synaesthesia at the time of testing (but see now Sagiv 2005; Sagiv et al 2006). We point out that some researchers have suggested that the term 'synaesthesia' should cover only those instances that involve a strict crossing of the senses (eg coloured hearing). It was not our aim to be overly prescriptive about what does or does not constitute synaesthesia, although we point out that non-prototypical instances (eg personifications) appear to co-occur with 'canonical' (cross-sensory) variants, and share many of their key characteristics (eg their automaticity, consistency, vividness, and early onset). Additionally, even apparently prototypical synaesthesias—such as coloured hearing triggered by spoken language—have recently been shown to be triggered by abstract cognitive representations, rather than purely perceptual processing (Dixon et al 2000; Simner et al 2006; Ward and Simner 2003). We would welcome a dialogue with other researchers whether certain manifestations included or omitted here represent a type of synaesthesia or not [eg the vivid, perceptual, and reliable olfactory sensations triggered when KL thinks of a person, and which Cytowic (1989) describes as a synaesthesia called 'olfactory memory']. Until then, our readers are at liberty to inspect table 1, and to calculate a prevalence of 'synaesthesia' according to their own definitional criteria. By any measure, however, it is hard to escape the conclusion that synaesthesia appears to be far more common than was previously assumed.

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