Original Article

QJEP

# "17" is odd and "seventeen" is even: Meaning and physical form in stimulus-parity synaesthesia

Quarterly Journal of Experimental Psychology
2018, Vol. 71(9) 2005–2021

DOI: 10.1177/1747021817738712
qjep.sagepub.com
SAGE

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**Abstract**

For individuals with stimulus-parity synaesthesia, eliciting stimuli (e.g., shapes, numbers, letters, colours) trigger a compelling feeling of oddness or evenness. Given that (a) many inducers are conceptual and (b) parity is itself a conceptual property, one questions whether stimulus-parity synaesthesia will be a categorically *higher* subtype, such that the conceptual properties of stimuli will be crucial in determining parity. We explore this question as it applies to Synaesthete R, one of only two stimulus-parity synaesthetes known to the contemporary literature. In Experiments 1 and 2, we examine whether parity is tied to concepts or percepts, asking, for example, whether a rectangle is *even* regardless of whether it is presented as an image or a word. Our results indicate that the parity of shapes (words and images), numbers (words, digits, and Roman numerals), and letters (lowercase and uppercase) differs according to the stimulus format, supporting a perceptual explanation. In Experiment 3, we examine the parity of colour stimuli, showing a systematic relationship between the measurable physical properties of hue, saturation, and lightness and synaesthetic parity. Despite the conceptual nature of inducers and concurrents, for Synaesthete R, stimulus-parity synaesthesia is a *lower* subtype; perceptual properties of stimuli determine parity.

**Keywords**

Conceptual associations; higher synaesthesia; lower synaesthesia; stimulus-parity; synaesthesia; perceptual associations

Received: 9 January 2017; revised: 29 July 2017; accepted: 1 September 2017

## Introduction

For most of us, the letter *E* is simply a letter, but for individuals with synaesthesia—a familial condition (Barnett et al., 2008; Rich, Bradshaw, & Mattingley, 2005; Ward & Simner, 2005) experienced by approximately 4% of the population (Simner et al., 2006)—the letter *E* may trigger an unusual sensory or conceptual experience. For example, in grapheme-colour synaesthesia, *E* may be red with an orange tinge; in sequence-personality synaesthesia, *E* may be a "cheeky chappy" who "talks when he doesn't know what he's talking about" (Simner & Holenstein, 2007, p. 696); in sequence-space synaesthesia, *E* may be positioned a metre in front of the synaesthete's left shoulder (Sagiv, Simner, Collins, Butterworth, & Ward, 2006); and in stimulus-parity synaesthesia (White & Plassart, 2015), which is the focus of this article, *E* may be experienced as a remarkably *even* letter.

The term synaesthesia—from *syn-* (joining) and *-aisthēsis* (sensation)—stresses sensation, but as the above examples illustrate, the phenomenon is remarkably broad (see Day, 2017; Mattingley, 2009), comprising atypical merging of both cognitive and sensory constructs (Simner, 2012). Simner notes that the "overwhelming majority of synaesthesiae appear to be triggered by the high-order cognitive constructs involved in language comprehension and production" (p. 3; see also Simner, 2007). The stimulus that triggers the synaesthetic experience is referred to as the *inducer*, and the resulting experience is referred to as the *concurrent* (Grossenbacher & Lovelace, 2001). Over the

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past two decades, there has been a fascinating line of research aiming to delineate the relationship between inducers and concurrents. One particularly interesting question is whether, for a given synaesthete, the concurrent is tied to the *meaning* or the *physical form* of the inducer and, thus, how deeply the inducing stimulus needs to be processed for the synaesthetic experience to arise (for an excellent discussion, see Chiou & Rich, 2014). Speaking to this distinction, Ramachandran and Hubbard (2001) have suggested that there are two types of synaesthete—those with higher synaesthesia and those with lower synaesthesia.

For *higher* synaesthetes, the conceptual/semantic properties of a stimulus are crucial in determining the concurrent. Thus, for an individual with grapheme-colour synaesthesia, the same colour is associated with the digit 1 and the word one (e.g., Ward & Sagiv, 2007), and the same colour is associated with the lowercase letter i and the uppercase letter I (Ramachandran & Hubbard, 2003; Whitaker, 2010), despite these inducers having a distinct visual appearance. Higher synaesthetes have a tendency towards synaesthetic experiences elicited by ordinal stimuli because ordinality is itself a conceptual property (Ward, Li, Salih, & Sagiv, 2007). Thus, sequence-space synaesthesia—in which ordinal sequences (e.g., letters, numbers, and weekdays) are visualised as occupying distinct spatial locations—is proposed to be a common experience of higher synaesthetes. Finally, for higher synaesthetes, synaesthetic concurrents tend to be experienced in the mind's eye (associator synaesthesia: Dixon, Smilek, & Merikle, 2004). In contrast, for *lower* synaesthetes, the perceptual properties of the inducing stimulus are crucial. Thus, for an individual with grapheme-colour synaesthesia, a different colour may be associated with the digit 1 and the word one, and a different colour may be associated with the lowercase letter i and uppercase letter I, despite these inducers having the same meaning, whereas the same colour may be associated with the digit 1 and the letter I because these inducers are visually similar (e.g., Palmeri, Blake, Marois, Flanery, & Whetsell, 2002). For lower synaesthetes, synaesthetic concurrents tend to be projected into external space (projector synaesthesia: Dixon et al.), such that an individual with grapheme-colour synaesthesia will see colour projected onto alphanumeric text, that is, "out there on the page" (p. 336). The vast majority of synaesthetes exhibit the higher subtype and demonstrate a relationship between inducers and concurrents that is based on *meaning* (Chiou & Rich, 2014; Simner, 2012).

In this article, we explore the relationship between inducers and concurrents as it applies to *stimulus-parity synaesthesia* (White & Plassart, 2015), a subtype of synaesthesia in which feelings of oddness and evenness—a conceptual notion—serve as the concurrent experience. Although reported cases of stimulus-parity synaesthesia are rare, the historical literature hints at the possibility that the phenomenon may be common. In a book chapter dedicated to personification phenomena, Flournoy (1893) briefly described his encounters with individuals who experienced many stimuli (e.g., weekdays, faces, types of food, "everything in the world," p. 233, translated from French by Plassart & White, 2017) as odd or even, and he suggested that the attribution of oddness and evenness to weekdays may be even more common than the attribution of gender to weekdays (as in sequence-personality synaesthesia). White and Plassart have subsequently described two individuals (R and M) who attribute oddness and evenness to many stimuli, including letters, numbers, weekdays, months, colours, and shapes.

There is good reason to anticipate that stimulus-parity synaesthesia will constitute a *higher* subtype and that the relationship between inducers and concurrents will be based on meaning. Many of the inducers in stimulus-parity synaesthesia are ordinal stimuli, and parity is itself a conceptual property, which by its very nature is experienced in the mind's eye (rather than external space). But despite the intuitive attractiveness of a hypothesis proposing meaning-based associations, Flournoy's (1893) writings hint at the possibility that synaesthetic parity can have a perceptual basis: He described one individual who experienced every face that he encountered as odd or even, depending on the length of the person's nose (see Plassart & White, 2017). Similarly, White and Plassart's (2015) two synaesthetes indicated a subjective impression of parity being based on the *look* of a stimulus. Here, we systematically assess the possibility of perceptual associations in this conceptual subtype of synaesthesia.

We present an extensive assessment of the inducer-concurrent pairings experienced by R. In Experiment 1, we focus on shapes (images and words), numbers (digits, words, and Roman numerals), and letters (lowercase and uppercase). If parity is tied to meaning, the same parity will be assigned to different representations of a given conceptual notion. For example, if the word rectangle elicits an even feeling, the image of a rectangle will also elicit an even feeling. If the word seventeen elicits an even feeling, the digit 17 and the Roman numeral XVII will also elicit an even feeling. In addition, if the lowercase letter q elicits an even feeling, the uppercase letter Q will also elicit an even feeling. In contrast, if parity is tied to physical form, a conceptual notion with different representations may produce divergent parity responses. Experiment 1 involves testing at two time-points, thereby providing information about consistency over time. We also include control participants, and their inclusion allows us to ask questions about the distinctiveness of R's associations. In Experiment 2, we focus on letter stimuli and hold constant stimulus meaning while manipulating physical form. In this experiment, we vary the font in which lowercase letters are presented. Finally, in Experiment 3, which again involves testing at two time-points, we investigate a new stimulus class for which clear perceptual hypotheses can be mounted. Specifically, we test 100 colours that differ in terms of hue, saturation, and lightness (HSL), and we investigate whether there are systematic relationships between each of these physical properties and synaesthetic parity.

## Case description

R is 33-year-old right-handed female, whose native language is English. She is highly educated, holding a PhD in Physics. She has various subtypes of synaesthesia: (a) sequence-space synaesthesia, with letters, numbers, time, weekdays, and months occupying three-dimensional shapes in the mind's eye and around the body; (b) grapheme-colour and lexical-colour synaesthesia, with a small selection of letters, numbers, weekdays, and months having colours; and (c) stimulus-parity synaesthesia, with letters, numbers, weekdays, months, colours, shapes, and words eliciting feelings of oddness and evenness. Consistent with the familial nature of the phenomenon, R's father is also a synaesthete. In a previous study (White & Plassart, 2015), R was shown to be highly consistent in her parity associations when given a surprise retest at 3 months. R reports that her parity associations have a subjectively automatic quality, and reaction time data is consistent with this impression (Dumbalska, White, Duta, & Nation, in press). We assessed R using a modified Stroop-type paradigm (MacLeod, 1991; Stroop, 1935). She was significantly faster to identify the spatial location of parity-congruent stimuli (e.g., an even shape presented against an even colour background) compared with parity-incongruent stimuli (e.g., an even shape presented against an odd colour background).

R reports that her parity associations can assist her with remembering information. For example, when attempting to recall a person's name or a phone number, she might remember there being an associated feeling of oddness, and this cue allows her to narrow the possible options (for a discussion of the helpfulness of synaesthetic associations, see Watson et al., 2017). For R, odd stimuli give a dark feeling, whereas even stimuli give a warm and light feeling. But two odd stimuli will not necessarily elicit the same feeling, nor will two even stimuli. The term oddness encapsulates a range of feelings, as does the term evenness. In discussing these *feelings*, she said that someone without synaesthesia might get the same feeling that she experiences when she encounters a strongly *odd* stimulus, if the person were walking through a dense pine forest, trees towering overhead and so closely packed that the lower branches have died away. Similarly, someone without synaesthesia might get the same feeling that she experiences for a strongly *even* stimulus, if the person were sitting in a warm car without air conditioning on a summer's day, driving past fields of sunflowers.

## Experiment 1: shapes, numbers, and letters

In Experiment 1, we set out to establish whether R's parity associations are tied to the meaning or physical form of inducers. To address this question, we present shapes (images and words), numbers (digits, words, and Roman numerals), and letters (lowercase and uppercase). If parity is tied to meaning, the same parity will be assigned to different representations of a given conceptual notion. In contrast, if parity is tied to physical form, a conceptual notion with different representations may produce divergent parity responses.

### Method

*Participants.* In addition to R, we also tested a control group of 10 non-synaesthetes who, prior to taking part in the experiment, had not associated *non-numerical* stimuli with oddness and evenness. Control participants (eight females, two males, aged 18-35 years, $M=21.6$ years) were recruited from the University of Oxford community, and all spoke English as their first language. Participants were compensated £7 for their time, and the study received ethical approval from the University of Oxford Ethics Committee.

*Stimuli.* There were seven stimulus categories (shape words, shape images, number words, digits, Roman numerals, lowercase letters, and uppercase letters). Fourteen *shapes* were presented as words (e.g., square) and as images (i.e., an outline). Twenty numbers (i.e., 1-20) were presented as words (e.g., four), digits (e.g., 4), and Roman numerals (e.g., IV). Twenty-six letters were presented in lowercase (e.g., a) and uppercase (e.g., A) font. Shape images were black, had a height of approximately 2.85° visual angle, and ranged in width from 1.9° to 3.8° visual angle. All of the other stimuli were presented in black, size 40 Arial font.

*Procedure.* The participant viewed stimuli on a laptop computer monitor. All stimuli were presented—one at a time—in the centre of the display on a white background. Items from each stimulus category were presented in a block so that the participant knew the intended membership of the presented item, for example, that the presented stimulus was the letter X as opposed to the Roman number 10. The participant was asked to write down whether each item *felt* odd or even. At the completion of the experiment, the participant was asked whether she had used a particular strategy to decide whether stimuli were odd or even and whether she was able to identify defining features of oddness and evenness.

*Consistency over time.* One measure of the genuineness of synaesthesia is the consistency of synaesthetic associations. We assessed the consistency of R's odd-even associations at 6 months and the consistency of control participants' odd-even associations at 2 to 3 weeks. Thus, to borrow terminology from Simner and colleagues (2005), we "stacked the deck" against R so as to test her consistency more conservatively. We used 66 stimuli from the experiment (Time 1) to test consistency at Time 2: eight shape words, eight shape images, 10 number words, 10 digits, 10 Roman numerals, 10 lowercase letters, and 10 uppercase letters. The procedure for presenting stimuli and recording parity was identical to Time 1.

## Results

We draw on the results of Experiment 1 to answer three main questions. The first question, and indeed the focus of the article, is whether parity—for R (and control participants)—is tied to stimulus meaning. If the data argue against meaning-based associations, a related sub-question is whether the parity of words and Roman numerals is determined by their constituent letters. The second question is whether any stimuli elicit consistent responses across control participants. A related sub-question is whether R's responses are the same as control participants for these items and, to this end, whether R and control participants share the same notions of what determines whether a stimulus feels odd or even. The third question is whether R's parity associations are more consistent than those of control participants.

*Question 1: Is parity tied to stimulus meaning?* Each participant's data were analysed using the Q′ test, which compares proportions in single case research (Michael, 2007). For *shape stimuli*, parity was classified as being tied to meaning if the participant provided the same parity attribution for at least 10 of 14 shape words and their corresponding images. For *number stimuli*, parity was classified as being tied to meaning if the participant provided the same parity attribution for (a) at least 14 of 20 number words and their corresponding digits, or (b) at least 14 of 20 number words and their corresponding Roman numerals, or (c) at least 14 of 20 digits and their corresponding Roman numerals. For *letter stimuli*, parity was classified as being tied to meaning if the participant provided the same parity attribution for at least 8 of the 11 letters that have visually dissimilar lowercase and uppercase representations.

*Synaesthete R.* R provided the same parity response for five of 14 shape words and their corresponding images (e.g., the word triangle and the triangle image were both odd) and a different parity response for nine of 14 shape words and their corresponding images (e.g., the word rectangle was odd and the rectangle image was even), $Q'(1)=1.95$, $p=.1629$ (see Table 1). We were wary that the results—no effect for meaning—may be swayed by three stimuli being described as neither odd nor even. Thus, in a second analysis, we classified the responses for a given shape (i.e., word and image) as being different only if one was odd and the other even, that is, we excluded those shapes ($n=3$) that had initially been classified as eliciting different responses across word and image representations due to a *neither* response. The results supported our first analysis in showing no effect for meaning, $Q'(1)=0.16$, $p=.6925$. Parity does not appear to be tied to particular shape concepts; thus, for example, it is not the case that the concept *rectangle* is even, but rather the outline of a rectangle is even and the word rectangle is odd.

With respect to *numbers*, we start by highlighting patterns in R's data. First, only three numbers (5, 9, and 11) generated the same parity response across the three stimulus sets. Second, for digits, R's responses were largely consistent with their actual numerical parity (i.e., numerically odd numbers were described as odd and numerically even numbers were described as even): The exception was the digit 3 which was described as even. Third, 16 Roman numerals were described as odd, and the remaining four (XII, XIV, XV, and XVIII) were neither odd nor even. Given these points, it seems unlikely that R's parity responses are based on the meaning of inducing stimuli. But we nonetheless conducted separate analyses comparing (a) words and digits, (b) words and Roman numerals, and (c) digits and Roman numerals.

R provided the same parity response for nine of 20 number words and their corresponding digits and a different parity response for 11 of 20 number words and their corresponding digits, $Q'(1)=0.31$, $p=.5773$. This result—no effect for meaning—held true when we excluded those numbers ($n=3$) that were initially classified as eliciting different responses due to a neither response, $Q'(1)=0.09$, $p=.7602$. She provided the same parity response for seven of 20 number words and their corresponding Roman numerals and a different parity response for 13 of 20 number words and their corresponding Roman numerals, $Q'(1)=2.92$, $p=.0873$. This result—no effect for meaning—held true when we excluded those numbers ($n=5$) that were initially classified as eliciting different responses due to a neither response, $Q'(1)=0.11$, $p=.7426$. Finally, she provided the same parity response for eight of 20 digits and their corresponding Roman numerals and a different parity response for 12 of 20 digits and their corresponding Roman numerals, $Q'(1)=1.26$, $p=.2611$. Again, this result—no effect for meaning—held true when we excluded those numbers ($n=4$) that were initially classified as eliciting different responses due to a neither response, $Q'(1)=1$, $p=1.000$. Parity does not seem to be tied to particular number concepts; thus, for example, it is not the case that the concept *seventeen* is even, but rather the word seventeen is even and the digit 17 and Roman numeral XVII are odd.

**Table 1.** Synaesthete R's parity responses (odd, even, neither) for the shape, numerical, and letter inducers presented in Experiment 1 and Experiment 2.

| Experiment 1 | | | | | | | | | | Experiment 2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shapes | | | Numbers | | | | Letters | | | | |
| | Word | Image | | Word | Digit | Roman numeral | | Lowercase, Arial | Uppercase, Arial | Lowercase, Gills Sans | Lowercase, Old English |
| Triangle | Odd | Odd | 1 | Even | Odd | Odd | aA | Odd | Odd | Odd | Odd |
| Moon | Even | Even | 2 | Odd | Even | Odd | bB | Odd | Even | Even | Odd |
| Rectangle | Even | Odd | 3 | Even | Even | Odd | cC | Even | Odd | Odd | Odd |
| Hexagon | Even | Even | 4 | Odd | Even | Odd | dD | Odd | Odd | Odd | Even |
| Circle | Odd | Even | 5 | Odd | Odd | Odd | eE | Even | Even | Even | Even |
| Star | Odd | Odd | 6 | Odd | Even | Odd | fF | Odd | Odd | Odd | Odd |
| Cross | Odd | Even | 7 | Even | Odd | Odd | gG | Even | Even | Odd | Odd |
| Rhombus | Even | Odd | 8 | Even | Even | Odd | hH | Neither | Odd | Odd | Odd |
| Diamond | Odd | Odd | 9 | Odd | Odd | Odd | iI | Odd | Odd | Neither | Odd |
| Octagon | Odd | Even | 10 | Even | Even | Odd | jJ | Odd | Odd | Even | Odd |
| Pentagon | Even | Odd | 11 | Odd | Odd | Odd | kK | Odd | Odd | Even | Odd |
| Oval | Neither | Odd | 12 | Even | Even | Neither | lL | Odd | Odd | Odd | Odd |
| Square | Neither | Even | 13 | Neither | Odd | Odd | mM | Even | Odd | Neither | Odd |
| Arrow | Odd | Neither | 14 | Odd | Even | Neither | nN | Neither | Odd | Odd | Odd |
| | | | 15 | Neither | Odd | Neither | oO | Even | Odd | Odd | Odd |
| | | | 16 | Neither | Even | Odd | pP | Even | Neither | Odd | Even |
| | | | 17 | Even | Odd | Odd | qQ | Odd | Odd | Odd | Odd |
| | | | 18 | Even | Even | Neither | rR | Odd | Odd | Odd | Odd |
| | | | 19 | Even | Odd | Odd | sS | Even | Odd | Even | Odd |
| | | | 20 | Even | Even | Odd | tT | Odd | Odd | Odd | Odd |
| | | | | | | | uU | Odd | Odd | Odd | Odd |
| | | | | | | | vV | Odd | Odd | Odd | Neither |
| | | | | | | | wW | Odd | Odd | Odd | Odd |
| | | | | | | | xX | Odd | Odd | Odd | Odd |
| | | | | | | | yY | Neither | Odd | Odd | Odd |
| | | | | | | | zZ | Odd | Odd | Odd | Even |

Finally, we present R's results for letter stimuli. Lowercase letters and uppercase letters were more likely to generate the same parity responses (17/26) than different parity responses (9/26), $Q'(1)=3.89$, $p=.0485$. The significance of this result was strengthened in a second analysis in which we excluded those letters ($n=4$) that were initially classified as eliciting different responses due to a neither response, $Q'(1)=11.95$, $p=.0005$. When reflecting on the question about whether it is the meaning or the physical form of the inducing stimulus that determines parity, we are particularly interested in those letters for which the lowercase and uppercase Arial representations are visually dissimilar, that is, aA, bB, dD, eE, gG, hH, lL, nN, qQ, rR, and tT. If the parity of letters is determined by meaning, the lowercase and uppercase versions of these letters should produce the same parity responses, despite their markedly different form. This was our finding for eight of 11 visually dissimilar lowercase letters and uppercase letters, $Q'(1)=4.32$, $p=.0378$. The effect for meaning was strengthened when we excluded those letters ($n=2$) that were initially classified as eliciting different responses due to a neither response, $Q'(1)=13.35$, $p=.0003$. We interpret the results as showing that, for R, parity *may* be tied to particular letter concepts.

*Is the parity of words and roman numerals determined by their constituent letters?* The parity of shape words diverged from that of the shapes that they represented, as did the parity of number words diverge from that of the digits to which they corresponded. We can test whether the parity of words is determined by their constituent letters, by comparing parity responses for words and their initial lowercase letter or initial lowercase vowel.

Twelve of 14 shape words generated parity responses. These words shared the same parity as the initial (lowercase Arial) letter in five instances and the initial (lowercase Arial) vowel in 11 instances. Eighteen of 20 number words generated parity responses. These words shared the same parity as the initial (lowercase Arial) letter in eight instances and the initial (lowercase Arial) vowel in 13 instances. Thus, initial letter parity does not predict word parity, as words were no more likely to have the same parity (13/30) as the initial letter, compared with the opposing parity (17/30), $Q'(1)=0.79$, $p=.3727$. In contrast, initial vowel parity may provide one explanation for how physical form determines word parity, as words were significantly more likely to have the same parity (24/30) as the initial vowel, compared with the opposing parity (6/30), $Q'(1)=24.69$, $p<.0001$.

Moving to Roman numerals, for R, 16 of 20 Roman numerals generated parity responses, and all 16 were experienced as odd. The first 20 Roman numerals include some combination of I and/or V and/or X, and not surprisingly, in our assessment of uppercase letters, R indicated that each of these three letters was odd. Thus, Roman numerals shared the parity of the initial letter (16/16), $Q'(1)=53.11$, $p<.0001$, and the parity of the only constituent vowel (15/15), $Q'(1)=49.54$, $p<.0001$.

*Control participants*. With regard to *shape*, there were four control participants who provided the same parity response for at least 10 (of 14) shape words and their corresponding images. For these four control participants, shape parity is tied to meaning. Considering control participants as a group, the number of "same" parity responses ranged from 7 to 14 ($M=9.8$). R was outside of this range, providing the same parity responses for five of 14 shapes.

With regard to *numbers*, we note that *all* control participants reported that, for most digits, parity aligned with true numerical parity. There were three control participants for whom the relationship between number concepts and parity was particularly strong, insofar as (a) at least 14 (of 20) number words and digits generated the same parity responses, as did (b) at least 14 (of 20) number words and Roman numerals, and (c) at least 14 (of 20) digits and Roman numerals. An additional four control participants showed this relationship for number words and digits only. Thus, for seven control participants, number parity is (at least partly) tied to meaning. Considering control participants as a group, for words and digits, the number of "same" parity responses ranged from 12 to 20 ($M=15.8$). R was outside of this range, providing the same parity responses for nine of 20 numbers. For number words and Roman numerals, the number of "same" parity responses ranged from 7 to 14 ($M=15.8$). Again, R was outside of this range, providing the same parity responses for six of 20 numbers. For digits and Roman numerals, the number of "same" parity responses ranged from 6 to 16 ($M=10.9$). R was at the lower end of this range, providing the same parity responses for eight of 20 numbers.

When all 26 *letters* were included in the analyses, there were nine participants for whom at least 17 (of 26) lowercase and uppercase letters generated the same parity responses. However, when we focused only on those letters for which the lowercase and uppercase Arial representations are visually dissimilar, there was only one participant who for whom at least eight (of 11) lowercase and uppercase letters generated the same parity responses. The implication is that for nearly all participants, it was the perceptual similarity of the remaining lowercase and uppercase letters, rather than their conceptual relationship, that led to parity responses being the same for different representations of the same letter. Interestingly, the one participant who provided the same parity responses for visually distinct lowercase and uppercase letter representations reported that the parity of letters was determined by their sound; thus, even for this participant, we cannot rule out a perceptual explanation. Considering control participants as a group, for visually dissimilar letters, the number of "same" parity responses ranged from 3 to 8 ($M=6.1$); R was on the top of this range, providing the same parity responses for eight of 11 letters (Figure 1).

*Is the parity of words and roman numerals determined by their constituent letters?* There was no single control participant for whom the parity of words was determined by constituent letters—either the initial letter or the initial vowel. In all cases, words were no more likely to have the same parity as the initial letter or vowel, compared with the opposing parity (all $p$s$>.1629$).

With respect to Roman numerals, one control participant showed an effect for initial letter, whereby Roman numerals were more likely to have the same parity as the initial letter (15/20) compared with the opposing parity ($p=.0028$). Two other control participants showed an effect for vowel, whereby Roman numerals containing an I were significantly more likely to share its parity than the opposing parity (both $p$s$=.0068$). For the remaining seven participants, the parity of Roman numerals was not determined by constituent letters.

*Question 2: Do any stimuli generate the same parity association across control participants?* An individual stimulus was classified as generating the same parity association across control participants, if at least nine of 10 control participants provided the same parity judgement. The confidence interval (CI) around this proportion (CI$=[0.60, 0.98]$) does not contain chance.

In total, 46 stimuli—four shape words, three shape images, 11 number words, 18 digits, four Roman numerals, two lowercase letters, and four uppercase letters—generated the same parity association across control participants. R's responses patterned with those of control participants for 28 of these 46 stimuli; this represents chance level (CI$=[0.49, 0.75]$). Here, we are perhaps less interested in digits, as every participant provided responses that mapped onto true numerical parity for at least 17 of the 20 stimuli. Thus, we present a second analysis in which we restrict our focus to the 28 non-digit stimuli. R's

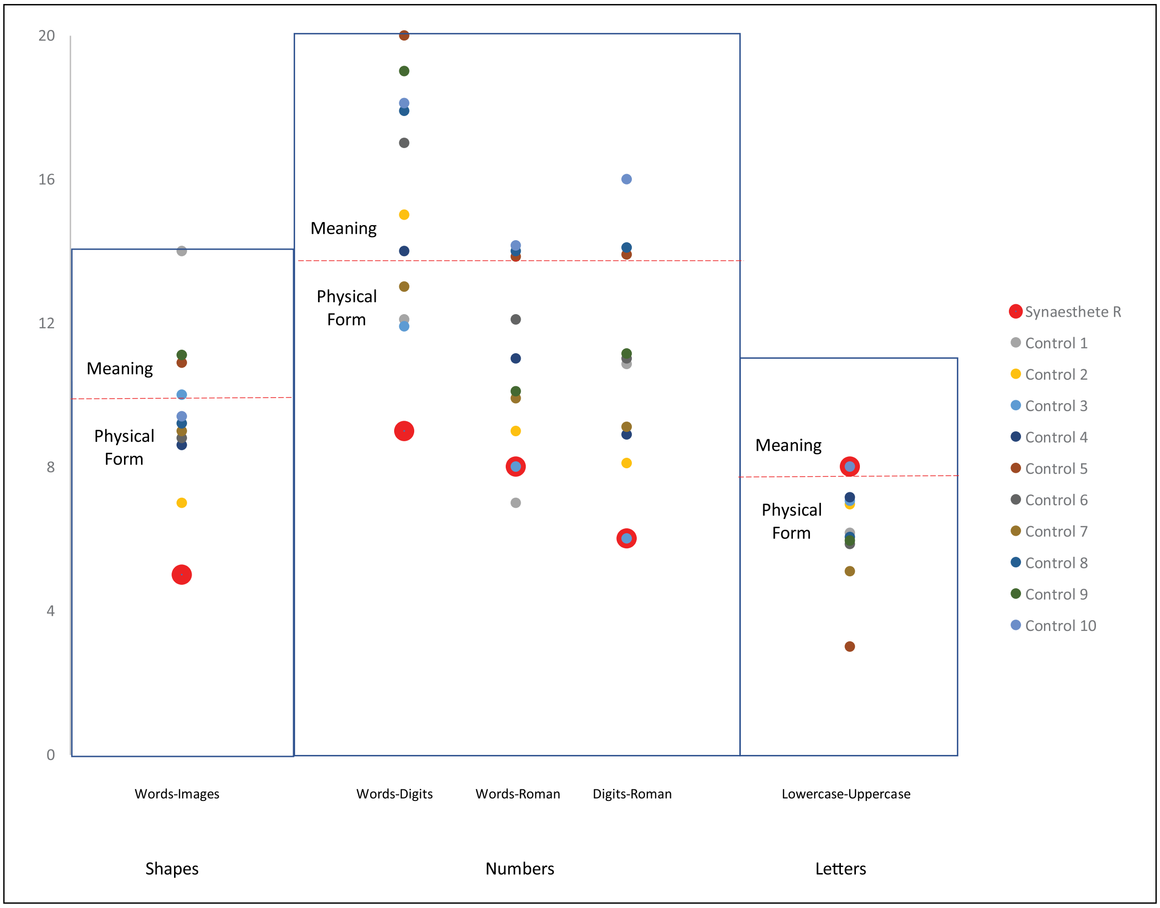


**Figure 1.** A graphical representation indicating the number of stimuli eliciting the "same" parity response across different representations, for each participant: shapes (words and images); numbers (words and digits; words and roman numerals; digits and roman numerals); and visually dissimilar letters (lowercase and uppercase). Note the dotted red line indicates the point at which a participant would be classified as responding on the basis of meaning (above) or physical form (below). Synaesthete R is represented by the large red circle.

responses patterned with those of control participants for only 11 of these 28 stimuli; once again, this result represents chance level (CI = [0.24, 0.58]).

The finding that R's responses were different to those of control participants, even for those items for which the responses of all control participants converged, is likely explained by differences in how control participants and R performed the task. Control participants tended to use fairly systematic strategies or rules for determining whether a stimulus should be classified as being odd or even. For example, seven control participants reported that even shapes had an even number of sides, nine control participants reported that even stimuli were symmetrical and/or round, and five control participants reported that odd stimuli were spiky. In contrast, R indicated that she was unable to pinpoint particular features leading to a stimulus being odd or even; parity was about an involuntary "feeling": odd things felt dark and even things felt light. She was reluctant to try to identify particular features that might tie with oddness and evenness and explained that doing so "would take the magic out of it . . . it would be like describing a three-dimensional world in two-dimensional terms . . . flat."

*Question 3: Are Synaesthete R's parity associations more consistent over time than control participants?* When given a surprise retest at 6 months, R's test-retest consistency was 94% (62/66). Control participants had a considerably shorter time period (2-3 weeks) between the initial test and the surprise retest. A Bayesian estimate (Crawford & Garthwaite, 2007) confirmed that the proportion of the control population likely to achieve fewer errors at retest than R was only 1.4% (CI = [0.002, 9.09]). Indeed, the mean consistency of control participants was 76% (50/66), and test-retest consistency ranged from 68% (45/66) to 86% (57/66). Thus, R was outside the range of all control participants, despite being tested at a much longer time interval and despite control participants reporting systematic strategies for ascribing oddness and evenness.

## Interim summary

We set out to explore whether R's parity judgements were based on stimulus concept or stimulus percept. We wondered, for example, whether it was the concept *rectangle* that elicited an even synaesthetic feeling or whether parity would differ depending on whether R was presented with an image of a rectangle versus the word rectangle. In Experiment 1, R and 10 non-synaesthetic control participants classified stimuli—shapes, numbers, and letters—according to whether they felt odd or even. It was important to include control participants so as to gauge whether R's stimulus-parity associations constitute an exaggeration of a normal process; perhaps all individuals experience a dichotomisation of stimuli along these dimensions, but for R the experience is more salient.

Participants classified stimuli at two time-points: For R, the initial test and the surprise retest were 6 months apart, whereas for control participants, the two tests were only 2 to 3 weeks apart. Despite the considerably shorter interval between their two testing sessions, control participants lacked the test-retest consistency demonstrated by R (94%). Their test-retest consistency (68%-86%), however, exceeded that of control participants in other synaesthesia experiments (i.e., around 20%; see Simner, 2012). This is likely explained by their use of systematic strategies. Also, as there were only two possible concurrents, chance performance was 50%, whereas in other studies, the choice of possible concurrents is wide-ranging (e.g., colours, personalities) so that chance performance is considerably lower.

Given that control participants lacked the test-retest consistency demonstrated by R, we are hesitant to draw steadfast conclusions regarding the conceptual versus perceptual nature of their associations. We do, however, tentatively point out patterns in the data. Control participants were able to articulate clear strategies for classifying stimuli as being odd or even. They reported that odd stimuli were asymmetrical, pointy, odd in terms of actual numerical parity, and had an odd number of sides, whereas even stimuli were symmetrical, round, even in terms of actual numerical parity, and had an even number of sides. As a general rule, control participants indicated that the task of assigning parity to letters was not at all intuitive. It was slightly more natural for shapes, given that these stimuli have a numerical component (i.e., number of sides), and considerably more natural for numbers. It is interesting and perhaps not surprising that for shape and number stimuli, control participants displayed a tendency towards more conceptual responses than R, whereas for letter stimuli, they displayed a tendency towards more perceptual responses than R. When tested on shapes, and specifically shape words, it is likely that the more conceptual control participants generated a mental representation of the corresponding image. These control participants were essentially assigning parity to the concept, rather than the specific representation in front of them. In contrast, the more perceptual responders may have applied the rules about symmetry and shape to the words (discounting their meaning), basing parity on the symmetry of the overall word or the pointiness/roundness of constituent letters. A similar argument can be mounted for numbers. The more conceptual control participants likely assigned parity to the number concept on the basis of true numerical parity, and this would explain the consistency across different stimulus representations. In contrast, the more perceptual responders tended to base the parity of digits on true numerical parity, but may have applied the rules about symmetry and shape to number words and Roman numerals, basing parity on the symmetry of the overall word or the pointiness/roundness of constituent letters. For letter stimuli, visually dissimilar lowercase and uppercase letters tended to elicit different parity responses among control participants. This is likely explained by the fact that letters do not have an obvious numerical component on which to base a more conceptual response; thus, the participants simply assigned parity to the stimulus in front of them, on the basis of rules about symmetry and shape.

Interestingly, many (non-numerical) stimuli elicited the same parity response across at least 90% of control participants. Importantly, R's responses diverged from those of control participants on approximately half of these items. We suggest that this is explained by the systematic strategies that control participants implemented and indeed articulated. R did not use a strategy as parity is an involuntary feeling that she gets on viewing a stimulus. Thus, control participants and R had a different phenomenological experience of the task: for control participants, sorting involved strategy, whereas for R it involved intuition.

In contrast to control participants, R found the task of assigning parity to shapes, numbers, and letters natural and enjoyable. R's parity judgements for shapes and numbers were not tied to stimulus meaning. Different representations of the same conceptual notion elicited different parity responses, supporting an account based on physical form. Indeed, the parity of shape words, number words, and Roman numerals was determined by the parity of the constituent letters. Interestingly, however, R's parity judgements for letters were largely case-invariant, with the same parity responses for visually dissimilar lowercase and uppercase letters. Our results for shapes and numbers are relatively straightforward—different parity responses for different representations of the same concept rule out meaning-based associations. In contrast, our results for letters are less straightforward—the same parity responses for different representations of the same concept do not automatically imply that associations are meaning-based. The lowercase letter g and the uppercase letter G may be even, not because parity is tied to the concept of g/G but rather because these two representations share a particular *perceptual* feature that is tied to evenness. Thus, a second experiment is warranted to tease apart conceptual and perceptual accounts.

## Experiment 2: lowercase letters and font

In Experiment 2, we alter the fonts in which lowercase letters are presented to test whether this manipulation to physical format affects parity. If the parity of letters does not change, this will add support to the conceptual account. In contrast, if the parity of letters does change, this will confirm the perceptual account.

### Method

*Stimuli.* Lowercase letters were presented in **Gill Sans Ultra Bold** and Old English Text MT, size 40 font. These two fonts are visually distinct—the first is a weighty font, and the second is a detailed and intricate font.

*Procedure.* The procedure was identical to Experiment 1.

### Results

We draw on the results of Experiment 2 to assess whether the parity of letters can be altered by the font in which a letter is presented. We contrast the parity responses for four types of letter stimuli—Arial lowercase and uppercase (Experiment 1), Gill Sans lowercase, and Old English lowercase (Experiment 2). Across the four fonts, letters were equally likely to generate consistent (10/26) and inconsistent (16/26) parity responses, $Q'(1)=2.14$, $p=.1439$. This held true when we excluded those letters ($n=6$) that were inconsistent only in terms of a neither response, $Q'(1)=0.00$, $p=1$. The findings from Experiment 2 argue against the interpretation that parity is tied to particular letter concepts.

### Interim summary

Following Experiment 1, we concluded that the parity of shapes and numbers was tied to physical format. Based on the results from Experiment 2, we can extend our conclusion about physical format to letters. By changing the font in which letters were presented, we were able to alter their parity. Thus, it is not the case that the letter *concept* g is even (for example), but rather that lowercase Arial-g and uppercase Arial-G are even, and different physical representations of g can result in different parity experiences.

Given our demonstration that parity is tied to physical form for R, an interesting question emerges: Can we identify (unconscious) rules that determine the parity of a stimulus? That is, do particular physical properties correspond with oddness versus evenness, or are stimulus-parity associations random? Much research has been directed towards this question as it applies to subtypes of synaesthesia in which colour serves as the concurrent. Here, we briefly describe three such subtypes: coloured hearing, grapheme colour, and sound colour. Baron-Cohen, Harrison, Goldstein, and Wyke (1993) tested nine individuals who experienced colours in response to verbally presented stimuli (e.g., words, letters), that is, *coloured hearing* synaesthesia. Across the nine synaesthetes, there was remarkable consistency in the synaesthetic colours elicited by the vowels *i, o*, and *u*. Eight of the synaesthetes reported that *i* was in the white to pale grey range, *o* was white, and *u* was in the yellow to light brown range. The researchers contrasted the colours that their synaesthetes experienced with those experienced by synaesthetes in the historical literature (e.g., Galton, 1883; Jordan, 1917) and identified that 73% of responses to the letter *o* were white.

Much research has explored whether graphemes and colours pair in a systematic way in individuals with *grapheme-colour synaesthesia*. Simner et al. (2005) found that many letters were associated with particular synaesthetic colours with a frequency far exceeding chance. Thus, for example, the letter *a* was frequently experienced as red (over 40%), the letter *o* as white (over 50%), and the letter *y* as yellow (over 40%). The researchers discovered that grapheme frequency was an important predictor of synaesthetic colour associations. High-frequency graphemes tended to pair with high-frequency colour terms, and high-frequency graphemes tended to pair with the earliest colour terms in Berlin and Kay's (1969) irreducible colour terms typology. Brang, Rouw, Ramachandran, and Coulson (2011) have shown that shape is also an important predictor of synaesthetic colour. Similarly shaped graphemes are associated with similar synaesthetic colours, and this is particularly true of projector synaesthetes. Following from this finding, Jürgens and Nikolic (2012) used a novel set of graphemes (i.e., graphemes constructed by the researchers for the purpose of research) to demonstrate the rapid speed with which synaesthetic colours are mapped onto newly encountered graphemes. The results supported those of Brang et al. in demonstrating the importance of shape, and more specifically, the researchers demonstrated that synaesthetic colours mapped onto graphemes on the basis of general shape dimensions, such as whether the graphemes were open versus closed, or angular versus round. Watson, Akins, and Enns (2012) investigated multiple grapheme properties simultaneously. They found that frequency predicted synaesthetic luminance, and shape and order (i.e., whether letters come early or late in the Latin alphabet) predicted synaesthetic hue. Similarly, Asano and Yokosawa (2013) found that shape and order predicted the synaesthetic colour of Latin letters, but they also demonstrated that different factors are predictive of synaesthetic colour across different writing systems; for Hiragana characters, order was the strongest predictor of synaesthetic colour, followed by sound and shape.

There is a large body of literature showing non-random patterning of pitch to colour in individuals with

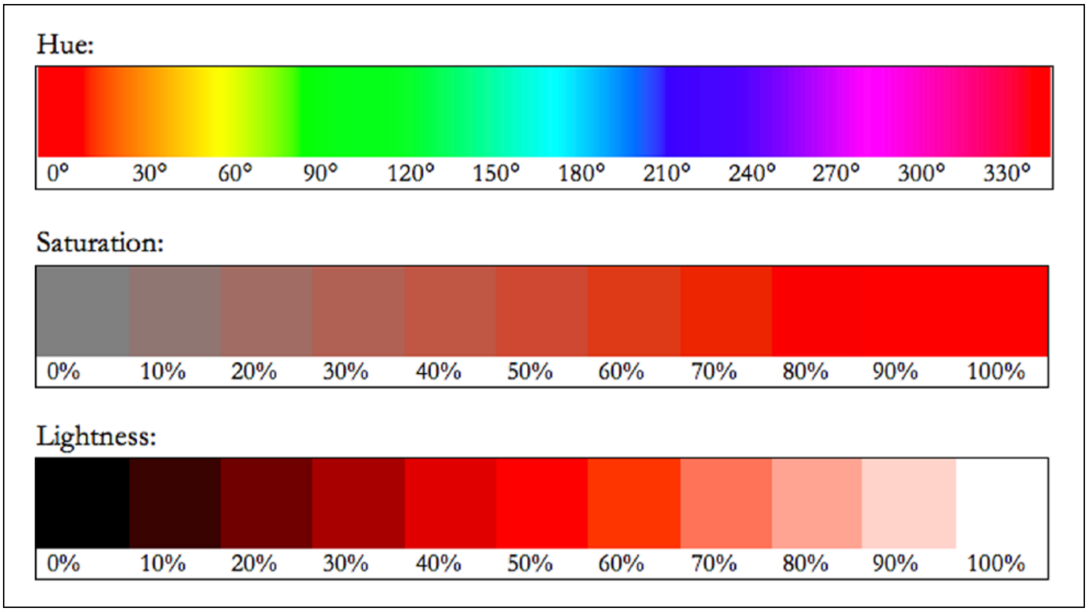


**Figure 2.** Three panels depict manipulations to hue, saturation, and lightness. The top panel holds saturation and lightness constant at 100% and 50%, respectively, and varies hue, starting with 0° on the left. The middle panel holds hue and lightness constant at 0° and 50%, respectively, and varies saturation. Each of the 11 squares of the panel represents a different level of saturation, starting with 0% on the left and increasing in increments of 10%. The bottom panel holds hue and saturation constant at 0° and 100%, respectively, and varies lightness. Each of the 11 squares of the panel represents a different level of lightness, starting with 0% on the left and increasing in increments of 10%.

*sound-colour synaesthesia*. Specifically, this literature shows that lower pitched sounds tend to elicit dark synaesthetic colours, whereas higher pitched sounds elicit lighter and brighter synaesthetic colours (Whitchurch, 1922; Zigler, 1930). The same pattern is true of non-synaesthetes who are asked to select a colour corresponding to a given pitch (Marks, 1974). Ward, Huckstep, and Tsakanikos (2006) have shown that additional properties of music, such as timbre, likewise exert a systematic effect on synaesthetic colour experiences. Whereas pitch refers to the highness or lowness of a tone, timbre is the quality of a musical note that allows us to distinguish the instrument of production, that is, voice, string instrument, wind instrument versus percussion, and so on. Ward et al. demonstrated that "musical notes from the piano and strings are, literally, more colourful than pure tones" (p. 270).

Colour stimuli are well suited to our question about systematicity in the relationships between inducers and concurrents in stimulus-parity synaesthesia. Not only does R report that colours elicit a compelling sense of oddness or evenness ("red is the most even thing in the world"; White & Plassart, 2015), but perhaps more importantly, we can identify and isolate different characteristics of colour and test the associations between these characteristics and parity.

## Experiment 3: colours

In Experiment 3, we explore whether the physical characteristics of a colour allow us to predict its categorisation as either odd or even, and we explore this question using the HSL colour categorisation system. HSL is one of many coordinate systems used to navigate three-dimensional colour space and to represent the relationships between different colours. HSL uses a cylindrical coordinate system, encompassing hue, saturation, and lightness. Figure 2 provides a visual representation of manipulations to hue, saturation, and lightness, respectively. *Hue* corresponds to the angular dimension in HSL space. It is a spectral property of colour which measures its degree of similarity to red, blue, yellow, and green (Koenderink, 2010). Thus, when talking about colours in everyday life, one tends to focus on this attribute. For instance, one would distinguish a red traffic light from a green traffic light on the basis of hue. Our definition of saturation makes reference to lightness, and we therefore describe lightness next. *Lightness* varies along the vertical axis of the HSL cylinder. Rather intuitively, the lower the lightness value, the darker a colour appears, and vice versa. Thus, at 0% and 100% lightness, one cannot distinguish the hue that is being represented; instead, the colours appear as black and white, respectively. Finally, *saturation* varies along the horizontal axis of the HSL cylinder. Colours with a high saturation value appear more vivid, whereas colours with a low saturation value appear achromatic or subdued. Indeed, colours with 0% saturation would appear as grey given that their lightness value is above 0% and below 100%. Thus, a colour with a saturation of 100% and lightness of 50% would appear very pure or vivid.

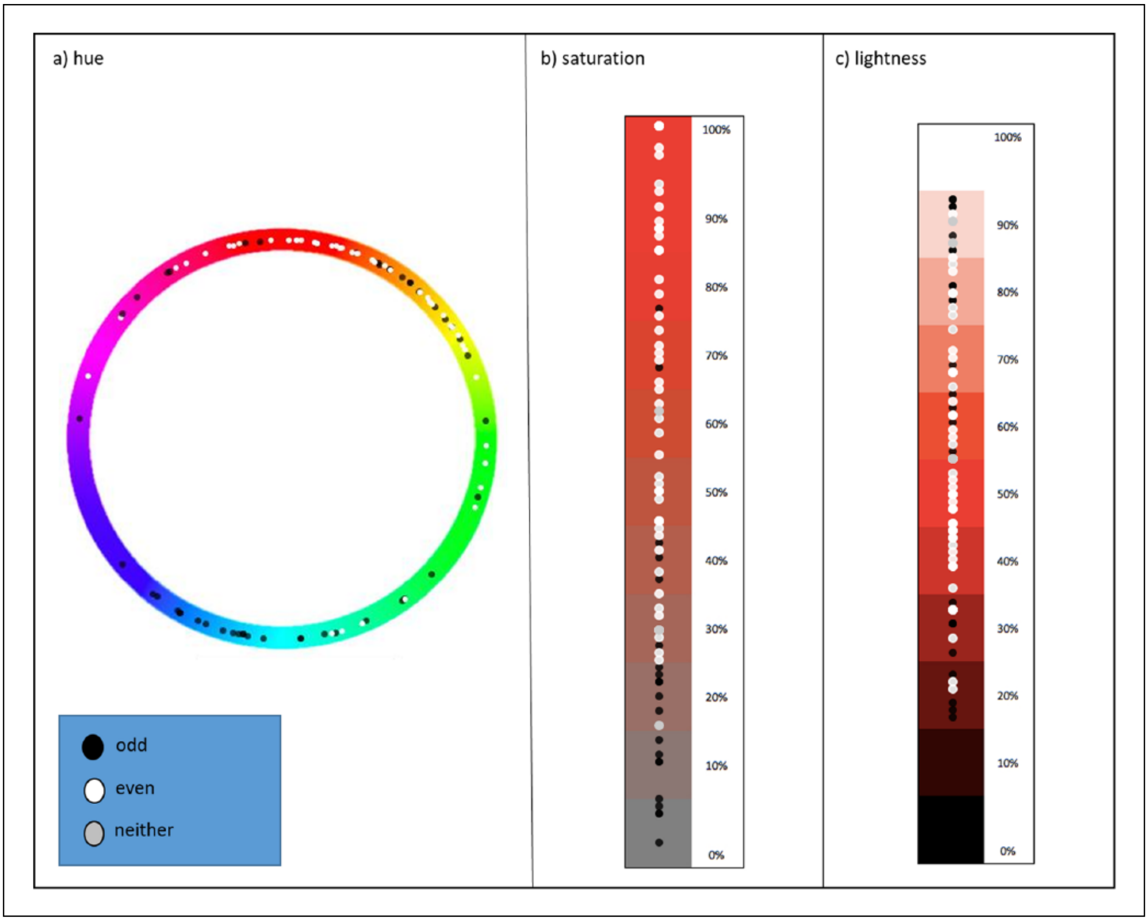


**Figure 3.** The relationship between (a) hue and parity, (b) saturation and parity, and (c) lightness and parity.

## Method

*Stimuli.* Stimuli comprised 100 Pantone colour cards. The cards measured 14.2 cm in height and 9.7 cm in width. Each card contained a uniquely coloured square measuring 9.7 cm × 9.7 cm. A panel on the bottom of each card, measuring 4.5 cm in height and 9.7 cm in width, contained the colour number presented in black on a white background.

*Procedure.* R was invited to sort the 100 cards into one of seven piles—extremely odd, moderately odd, slightly odd, neither odd nor even, slightly even, moderately even, and extremely even. The cards were randomised and presented to R in a deck. To ensure that her attention was directed to the coloured square, the numbered panel at the bottom of each card was covered. The experimental room was lit naturally to provide optimal conditions for observing the colour of the cards.

*Consistency over time.* We assessed the consistency of R's odd-even associations at 11 months. The procedure for presenting stimuli and recording parity was identical to Time 1.

## Results

We draw on the results of Experiment 3 to assess whether there are systematic relationships between hue, saturation, and/or lightness and parity.

*Question 1: Is there a systematic relationship between hue and parity? Hue* is measured in degrees, and it is often visualised on a wheel or circle. In Figure 3, we provide a visual representation of the relationship between hue and parity. Visual inspection of this figure reveals a general pattern, whereby even parity judgements cluster on the top of the circle (i.e., between 360° and 60°) and odd parity judgements cluster at the bottom-left of the circle (i.e., between 150° and 240°). Note that these two sections of the hue wheel comprise colours normally labelled red and blue, respectively. Thus, *distance from red*, which R reports "is the most even thing in the world," may be important in determining the parity of different hues.

To investigate this hypothesis, we examined whether odd and even colours differ in their distance from the hue value of 0° (or 360°), that is, for cards with hues between 0° and 180°, we measured the absolute distance of the hue from 0°, and for cards with hues between 180° and 360°, we measured the absolute distance of the hue from 360°. The resulting value provided an estimate of each card's *distance from red*. Mean absolute distance from 0° (or 360°) for odd cards was 107° and the mean absolute distance from 0° (or 360°) for even cards was 47°. This difference was statistically significant, $t(98) = 5.94$, $p < .001$. In addition, there was a negative linear correlation between the nuanced parity ratings (−3 to +3) and distance from 0° (or 360°), $r = -.538$, $p < .001$, $N = 100$. The closer a hue to the top of the hue wheel, the *more even* its parity. Conversely, the more distant a colour from the top of the hue wheel, the *more odd* its parity.

*Question 2: Is there a systematic relationship between saturation and parity?* The average saturation of odd cards was 34% (standard deviation [SD] = 24%) and the average saturation of even cards was 68% (SD = 25%). This difference was statistically significant, $t(100) = 6.770$, $p < .001$. Thus, odd cards were more subdued (i.e., more achromatic) and even colours were more saturated (i.e., pure). This was confirmed in our finding of a positive linear correlation between the nuanced parity ratings (−3 to +3) and saturation (0%-100%), $r = .624$, $p < .001$, $N = 100$. The more saturated a colour, the *more even* its parity. Conversely, the less saturated a colour, the *more odd* its parity.

*Question 3: Is there a systematic relationship between lightness and parity?* The average lightness of odd cards was 56% (SD = 17%) and the average lightness of even cards was 58% (SD = 24%). This difference was not significant, $t(100) = -0.504$, $p = .616$. Given the definition of lightness, this result is perhaps not surprising. Lower lightness values indicate a darker colour, whereas higher lightness values indicate a lighter colour. Thus, a lightness value around 50% indicates a purer colour, that is, a colour that does not appear too light or too dark. This is to be contrasted with saturation, for which a value of 100% indicates a brighter colour, that is, a colour that does not appear grey or subdued. Recall that our analysis of saturation indicated that colours that are purer (i.e., colours with a high saturation value) are more likely to be judged as even.

To investigate whether this pattern was also true of lightness, we conducted a second analysis in which we examined whether odd and even colours differ in their distance from the lightness value of 50%. We transformed the lightness variable so as to calculate the mean absolute distance from 50% for cards in the odd and even piles. Absolute values were used because lightness values of 25% and 75%, for example, are equally extreme. As predicted, odd cards had a mean absolute distance from 50% that was significantly greater ($M = 22.95\%$, $SD = 10.47\%$) than that of even cards ($M = 13.98\%$, $SD = 10.89\%$), $t(98) = 4.131$, $p < .001$. Thus, even colours were purer; they comprised less white and black than odd colours. This was supported by our finding of a positive linear correlation between the nuanced parity ratings (−3 to +3) and deviation from a lightness value of 50%, $r = -.463$, $p < .001$, $N = 100$. The more extreme the lightness value (i.e. high or low) of a colour, the *more odd* its parity. Conversely, the closer a colour's lightness value is to 50%, the *more even* is its parity.

*Consistency over time.* When given a surprise retest at 11 months, R's test-retest consistency was 95% (95/100).

### Interim summary

The patterns that we identified in R's colour-parity attributions sit beautifully with the patterns shown for other subtypes of synaesthesia. Just as letter frequency, shape, sound, and order can affect colour concurrents in grapheme-colour synaesthesia and pitch and timbre can affect colour concurrents in music-colour synaesthesia, so too can hue, saturation and lightness affect parity concurrents in stimulus-parity synaesthesia. The results suggest that, for R, hue, saturation and lightness are all important determinants of a colour's parity. Blue hues, low saturation, and extreme lightness are predictive of oddness, and red hues, high saturation, and moderate lightness are predictive of evenness.

## General discussion

Stimulus-parity synaesthesia presents as a conceptual subtype of synaesthesia, insofar as both the inducers and concurrents are conceptual notions rather than sensory experiences. Given the conceptual nature of this phenomenon, we anticipated that synaesthetic parity would be transferred across different stimulus formats on the basis of meaning. But the results from R paint a different picture: parity of shapes, numbers, letters, and colours was shown to be tied to physical format.

We do not presume that all stimulus-parity synaesthetes will demonstrate the same patterning between inducers and concurrents. But we think this case study constitutes an important demonstration that the conceptual nature of the phenomenon does not mean that all associations are meaning-based. This is in contrast to other novel formats of synaesthesia—for example, swimming-style colour synaesthesia (see Nikolić, Jürgens, Rothen, Meier, & Mroczko, 2011; Rothen et al., 2013)—which have been described as being categorically conceptual. In swimming-style colour synaesthesia, the concept of a swimming style (e.g., breaststroke) elicits a colour that is constant across different representations (i.e., whether the swimming style is performed, imagined, or visually depicted).

We divide the "General Discussion" section into three parts. First, we consider the evidence that stimulus-parity associations constitute a type of synaesthesia, referring both to data from R and control participants. Second, we examine how the constituent letters of a Roman numeral or word may determine its overall parity. And third, we ponder evidence for an interplay of meaning and physical form. Throughout each of our three sections, we try to contextualise our findings within the wider synaesthesia literature.

## *Are stimulus-parity associations synaesthesia?*

More than 80 subtypes of synaesthesia have been proposed (Day, 2017). Some of the more recently described subtypes include swimming-style colour synaesthesia (Nikolić et al., 2011) in which the concept of a swimming style elicits a colour and ordinal linguistic personification (also referred to as sequence-personality synaesthesia; Simner & Holenstein, 2007) in which linguistic units are attributed with gender and/or personality. When researchers uncover new variants of synaesthesia, they go to lengths to demonstrate the genuineness of the particular subtype, working through various *diagnostic* criteria. Here, we follow suit, synthesising the evidence that R's stimulus-parity associations constitute a subtype of synaesthesia.

The first point to note is that R shows other well-established subtypes of (e.g., sequence-space synaesthesia, grapheme-colour synaesthesia, lexical-colour synaesthesia). This is important as different variants of synaesthesia are known to co-occur (Simner et al., 2006). Second, R's father also experiences stimulus-parity associations. Again, this is important as synaesthesia is known to be hereditary (Barnett et al., 2008; Baron-Cohen, Burt, Smith-Laittan, Harrison, & Bolton, 1996). Third, R's associations are stable over time. In a previous study (White & Plassart, 2015), she was shown to be consistent for verbally presented stimuli at 3 months, and in this article, we show that her consistency extends to visually presented materials re-tested at longer timeframes: R was highly consistent for shape, number, and letter stimuli presented at a 6-month interval and for colour stimuli presented at an 11-month interval. Indeed, her test-retest consistency outshines control participants without synaesthesia who were tested after only 2 to 3 weeks. This is important as consistency—either over time (Simner et al., 2006) or within a single testing session (Carmichael, Down, Shillcock, Eagleman, & Simner, 2015)—is regarded as a behavioural gold standard for synaesthesia, although Simner (2012) presents a persuasive argument against viewing consistency as a *necessary* feature of the condition (see also Niccolai, Jennes, Stoerig, & Van Leeuwen, 2012). Fourth, R's stimulus-parity associations occur involuntarily; when two parity-incongruent stimuli are paired, processing speed is slowed. This is important because a defining feature of synaesthesia is the involuntary elicitation of the concurrent (e.g., oddness/evenness) following presentation of an inducer (Dumbalska et al., in press).

In addition to each of these points, we draw further support for the synaesthetic nature of R's stimulus-parity associations by contrasting her performance in the experiment with that of non-synaesthetic control participants. R showed a type of letter-to-word transference that is characteristic of synaesthesia; shape and number words were experienced as having the same parity as their initial vowel. None of the control participants showed this effect. Second, R found the task of associating stimuli with parity to be the most natural and intuitive of assignments. In contrast, control participants reported that the task was unintuitive. And yet, there were many stimuli for which *at least* nine of 10 control participants provided the same parity response. Importantly, on approximately half of these stimuli, R's parity response diverged from that of the control group. Thus, we would suggest that for control participants, the task involved something *akin* to crossmodal mapping (see Deroy & Spence, 2013; Woods, Spence, Butcher, & Deroy, 2013). According to the semantic hypothesis (Osgood, Suci, & Tannenbaum, 1957, cited in Woods et al., 2013) of crossmodal associations, different stimuli can be associated with one another because they share dimensions that anchor on polar adjectives, such as good/bad and active/passive. Thus, for example, angular shapes and bitter tastes may be paired because angularity and bitterness both anchor together as bad stimuli. If we extend this logic to the current experiment, it is possible that certain stimuli were overwhelmingly assigned to one parity group because of shared associations with oddness and evenness and particular polar adjectives. Thus, for example, for nine control participants, the word diamond was even. Perhaps diamond and evenness anchor strongly on the good end of the good/bad dimension. Deroy and Spence (2013) distinguish crossmodal correspondences from synaesthesia. They note that the former involves a *tendency* for sensory features or attributes in one modality to be paired with those in another, whereas the latter involves a genuine atypical *conscious* experience. This distinction sits nicely with our findings; when control participants viewed a stimulus, they were *able* to *assign* parity, whereas R was *unable* to view a stimulus without *experiencing* parity.

To summarise, we believe there are sufficient grounds on which to argue that stimulus-parity associations, as experienced by individuals such as R, constitute a form of synaesthesia. On viewing, hearing, or thinking about an inducing stimulus, R experiences an immediate and involuntary feeling of oddness or evenness. In most cases, so vivid is the feeling that R questions the possibility that anyone would experience a stimulus differently. The mere suggestion that another person might look at a stimulus and not perceive its parity is baffling to her. When control participants without synaesthesia are invited to assign parity to stimuli, there are commonalities in their attributions and these are not shared by R. These commonalities may be explained by natural (or at least explainable) crossmodal associations between stimuli. Many of R's associations, by contrast, are more idiosyncratic and less easily explained.

### *Words, roman numerals, and colours: support for the perceptual account*

Words served as an interesting stimulus in the current set of experiments. We found that the parity of shape words diverged from that of the shapes that they represented, as did the parity of number words diverge from that of the digits to which they corresponded. Thus, we questioned whether the parity of words was tied to the parity of constituent letters. Not dissimilarly, we questioned whether the parity of Roman numerals was tied to the parity of constituent letters. For other subtypes of synaesthesia, letter composition has been shown to affect performance in behavioural tasks and to determine the identity of concurrents. For sequence-personality synaesthetes—individuals who ascribe gender and/or personality to ordinal linguistic units—a letter-to-word transference effect has been documented (see Simner & Holenstein, 2007; Simner & Hubbard, 2006). Synaesthetes are faster to report whether a name (e.g., "Bob") is typically male or female, when it shares the synaesthetic gender of the initial letter (e.g., B = male). For lexical-colour synaesthetes, the synaesthetic colour of words has been shown to be determined by the initial letter, the initial vowel (Ward, Simner, & Auyeung, 2005), or the stressed vowel (see Simner, Glover, & Mowat, 2006). As we used noun stimuli, we were not able to disambiguate between explanations based on the initial vowel and stressed vowel, because for noun stimuli, these two tend to be confounded (Simner et al., 2006). We could, however, assess for relationships between serial position and word parity, focusing on the initial letter and the initial vowel of shape and number words. For R, there was a significant relationship between the parity of the initial vowel in a word and the parity of the overall word.

For Roman numerals, R demonstrated a significant relationship between the parity of initial letters, vowels, and Roman numerals. We note parallel findings in the historical literature (Lay, 1896) for three sisters (D, C and K) with grapheme-colour synaesthesia. For each of the three sisters, the colour of Roman numerals was determined by the letters comprising them, rather than the number to which they corresponded (see also Bridgeman, Winter, & Tseng, 2010). In contrast, Ward and Sagiv (2007) describe a grapheme-colour synaesthete who experienced corresponding colours for digits, number words, dots on a dice, outstretched fingers, and Roman numerals. In addition, Ramachandran and Hubbard (2001) reported two individuals with grapheme-colour synaesthesia, who experienced colours for digits but *not* for Roman numerals.

The most direct support for a perceptual account comes from Experiment 3 in which we collected parity ratings for 100 different colour cards. Each colour has a specific HSL value, and as such, we were able to test for quantifiable relationships between each of these stimulus properties and synaesthetic parity. Our results demonstrated systematic relationships: namely, blue hues, low saturation, and extreme lightness were shown to be predictive of oddness, and red hues, high saturation, and moderate lightness were shown to be predictive of evenness. Our results map onto previous synaesthesia studies in showing systematic relationships between inducers and concurrents (e.g., Asano & Yokosawa, 2013; Baron-Cohen et al., 1993; Brang et al., 2011; Jürgens & Nikolic, 2012; Simner et al., 2005; Ward et al., 2006; Watson et al., 2012; Whitchurch, 1922; Zigler, 1930). A novel aspect of our work is that whereas these previous studies have largely focused on colours as the concurrent, we used colours as the inducing stimuli.

### *Are there hints that meaning affects parity?*

Numerical stimuli have parity in the mathematical sense of being numerically odd or even, and they also have synaesthetic parity. Although the three representations of numbers—words, digits, and Roman numerals—elicited different parity responses for R, the parity of digits followed true numerical parity (i.e., numerically even numbers were classified as even and numerically odd numbers were classified as odd). It is probable that R learned about the concepts of oddness and evenness when learning digits. As a result, it may be particularly difficult to disentangle true numerical parity and synaesthetic parity. Relatedly, R reports that the word *odd* feels odd and the word *even* feels even. Parallel findings have been shown for other subtypes of synaesthesia, whereby an inducer that holds a particular meaning elicits a synaesthetic experience that is consistent with that meaning. In coloured-hearing synaesthesia, spoken words (e.g., cat, tree, star, person) elicit a synaesthetic experience of colour. When *colour* names (e.g., red) are presented, synaesthetes generally report that the synaesthetic colour matches the meaning of the word; thus, the word *red* is red in synaesthetic colour, and the word *blue* is blue in synaesthetic colour. Only rarely will synaesthetes experience an "alien colour effect" whereby synaesthetic colour does not match the meaning of the word (Gray et al., 2006). As but another example, in lexical-gustatory synaesthesia, words elicit a synaesthetic taste. The synaesthete may report that food-related words share the taste of the food that they represent. For example, case JIW, whose subjective synaesthetic tastes were experienced in the mouth and on the tongue, reported that the word *cabbage* tasted of cabbage, and in an assessment conducted by Ward and Simner (2003), JIW showed this effect for 41 of 44 food-related words. The only exceptions were alcohol-related words, for which JIW presumably developed synaesthetic tastes before encountering their actual taste.

Why is it that the parity of a Roman numeral or number word is determined by its constituent letters, whereas the parity of digits is determined by stimulus meaning? Perhaps because Roman numerals and words are a less familiar format for the presentation of numbers. Indeed, when it comes to Roman numerals, it may take longer to deduce the *meaning* of a Roman numeral (compared to a digit); R may need to translate the Roman numeral, letter-by-letter, to determine the number that it represents, whereas the meaning of a digit is more readily available. Consistent with this proposal, Perry (1952) showed an increased speed of reading digits (i.e., Arabic numerals) over Roman numerals of 50.1% for the numbers 1 to 9 (183.9 vs 122.5 per minute) and 137.5% for the numbers 10 to 49 (122.5 vs 50.1 per minute). As expected, error rates were significantly higher for Roman numerals. It would be interesting to test R on a larger set of Roman numerals and, specifically, to use longer letter strings representing numbers of higher magnitude. Our prediction is that R may indicate the synaesthetic parity of an item before she is able to indicate the number that it represents, that is, for Roman numerals, synaesthetic parity will likely precede deduction of meaning.

Just as the parity of digits mapped onto true numerical parity, thus hinting at a role for meaning, so too did the parity of regular shapes (triangle, square, pentagon, hexagon, octagon)—those with sides of equal length and equal internal and external angles—map onto the number of sides. Again, this hints at a possible role for meaning, although we do not have the power to test this statistically, and it is of course possible that this neat mapping is just a happy coincidence.

## Conclusion

At the outset of the article, we predicted that stimulus-parity synaesthesia would constitute a *higher* form of synaesthesia, such that the conceptual properties of stimuli would be crucial in determining parity. Our prediction was based on the conceptual nature of inducers and the fact that parity is itself a conceptual property. But we found that the perceptual properties of stimuli were crucial in determining parity for R, as is characteristic of lower synaesthesia. By its very nature, notions of parity are experienced in the mind's eye (i.e., associated with stimuli rather than projected onto stimuli). Some researchers have suggested that all associator synaesthetes are higher synaesthetes (e.g., Dixon et al., 2004), whereas others have argued that separate mechanisms give rise to each of the higher-lower and associator-projector distinctions (Ward et al., 2007; Ward & Sagiv, 2007). These arguments have mainly been advanced with regard to grapheme-colour synaesthesia. The current case—a lower-associator synaesthete—allows us to speak to this debate, as it applies to stimulus-parity synaesthesia. We support Ward and colleagues in the view that the higher-lower and associator-projector distinctions are distinct.

As we access more participants, it will be fascinating to examine whether this case is representative of the broader experiences of individuals with stimulus-parity synaesthesia. Questions of this nature have been addressed with respect to other subtypes of synaesthesia. For example, in grapheme-colour synaesthesia, case-study investigations have demonstrated colour associations tied to meaning (e.g., Ward & Sagiv, 2007) and colour associations tied to physical form (Palmeri et al., 2002), but a comprehensive group study (Rich et al., 2005) has shown that meaning-based associations are significantly more common. The study comprised 192 self-reported synaesthetes, and 150 of these synaesthetes reported that letters, digits, and words elicited colours. Questionnaire responses indicated that for approximately 70% of these individuals, colour was tied to the meaning of the inducing stimulus, that is, the colour for the digit 2 was the same as the colour for the word two. In contrast, for approximately 30% of these individuals, colour was instead tied to the physical form of the inducing stimulus.

Reflecting upon stimulus-parity synaesthesia, we wonder whether there may be an effect for the number of inducing stimuli or stimulus categories, such that individuals with few inducing stimuli may experience parity based on either meaning or physical form, whereas individuals with a substantial number of inducing stimuli may be more likely to experience parity based on physical form. Flournoy (1893) reported that some individuals experience parity in response to "everything in the world." Presumably though, as the pool of inducing stimuli increases, the likelihood that the individual knows the meaning of each stimulus decreases. Indeed, at the completion of this experimental series, we showed R some Chinese characters. Despite not knowing the *meaning* of the characters, R experienced an immediate sense of parity for each item. We suggest that an individual with higher synaesthesia would not experience parity in this context.

It is exciting to contemplate the wealth of information that will be provided by group-study investigations of stimulus-parity synaesthesia. There is a growing literature aimed at understanding how stimuli are categorised by neurologically healthy individuals without synaesthesia. This literature addresses questions about how categorisation proceeds in the developing child and the role it plays in facilitating memory and language (Mareschal, Powell, & Volein, 2003), the role of perceptual attributes in category development (Bornstein & Arterberry, 2010), the structure of categories (e.g., hierarchical inclusiveness, taxonomies; Bornstein & Arterberry, 2010), and the flexibility of categorisation along different stimulus dimensions, as demonstrated by children and adults (Oakes, Plumert, Lansink, & Merryman, 1996; Schyns & Rodet, 1997). Stimulus-parity synaesthesia provides a special case of dichotomous categorisation, and the questions that are being explored in the more general categorisation literature have direct relevance to this subtype. As we build up a larger database of individuals with stimulus-parity synaesthesia, it will be fascinating to integrate research on stimulus categorisation in individuals both with and without synaesthesia.

## Acknowledgements

The authors extend their gratitude to Synaesthete R and the control participants. Thanks also to Nicholas Hales, Hannah Smithson and the Oxford Perception Lab for exceptionally helpful discussions, and to Marcus Watson and the anonymous Reviewers for constructive feedback.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Rebekah White received a grant from Christ Church to help with costs associated with this research project.

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