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An exploratory study of linguistic–colour associations across languages in multilingual synaesthetes

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In one of the most common forms of synaesthesia, linguistic–colour synaesthesia, colour is induced by stimuli such as numbers, letters, days of the week, and months of the year. It is not clear, however, whether linguistic–colour synaesthesia is determined more by higher level semantic information—that is, word meaning—or by lower level grapheme or phoneme structure. To explore this issue, we tested whether colour is consistently induced by grapheme or phoneme form or word meaning in bilingual and trilingual linguistic–colour synaesthetes. We reasoned that if the induced colour was related to word meaning, rather than to the acoustic or visual properties of the words, then the induced colours would remain consistent across languages. We found that colours were not consistently related to word meaning across languages. Instead, induced colours were more related to form properties of the word across languages, particularly visual structure. However, the type of inducing stimulus influenced specific colour associations. For example, colours to months of the year were more consistent across languages than were colours to numbers or days of the week. Furthermore, the effect of inducing stimuli was also associated with the age of acquisition of additional languages. Our findings are discussed with reference to a critical period in language acquisition on synaesthesia.

Keywords: Synaesthesia; Language acquisition; Multilingual; Inducer; Concept; Critical period.

Synaesthetes experience a sensory mixing whereby a stimulus presented to one modality elicits a secondary sensory–perceptual experience in the same or different modality (Cytowic, 1989). Linguistic inducers account for around 92% of all reported cases of synaesthesia (e.g., Barnett et al., 2008), and colour for letters or numbers is experienced by 1–2% of the general population (Simner et al., 2005). Interestingly, colour is not specific to the input modality of the inducer and can be elicited when an inducer is presented in the auditory modality (i.e., the sound of the word), the visual modality (i.e., the written word), the tactile modality (i.e., when a letter is felt; e.g., Newell, Kilroy, & Chan, 2008) or even when simply thought about (Dixon, Smilek, Cudahy, & Merikle, 2000; Mills et al., 2002). Any of the senses can combine in synaesthesia; however, in the overwhelming

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majority of cases colour inducers are linguistic stimuli such as letters of the alphabet, numbers, days of the week, months of the year, and other general words. Moreover, the characteristic colour associations of linguistic–colour synaesthesia in a primary language can be influenced by typography, phonetics, and concept (Simner, 2007).

Given that linguistic stimuli are the most common inducers of synaesthesia and that the experience is typically present from early childhood (Cytowic, 1989, 1993), it is not implausible to suggest that synaesthesia is associated with a critical period associated with language acquisition (Rich, Bradshaw, & Mattingley, 2005). The fact that children acquire their primary language early in life and are faster and more efficient than adults at learning a second language has led to the hypothesis that there is a "critical period" for language acquisition (Curtiss, 1977; Lenneberg, 1967). To the best of our knowledge the assumption that associations between language inducers and synaesthetic concurrents might be associated with a critical period has not been tested (although Ward & Simner, 2003, found evidence for such a period with synaesthetic tastes). Furthermore, little is known about the influence of synaesthetic colour associations on languages other than the primary language (although Rich et al., 2005, noted that in their sample, significantly more synaesthetes than nonsynaesthetes spoke at least one other language).

There are, however, a number of single-case reports of multilingual synaesthetes that have provided some insight into the level of information processing required of the stimulus to induce colour. Most of these case studies have reported that colour is induced by low-level properties of the word (i.e., grapheme or phoneme) rather than meaning. For example, Cytowic (1993) describes a polyglot synaesthete, J.M., whose colours for words in different languages were determined by the individual letters of the word, rather than the meaning of the word. Similarly, Mills et al. (2002) report a multilingual synaesthete, M.L.S., for whom the colour of words was determined by the colour of the first letter of the word. Interestingly, M.L.S. experiences colour for two very different alphabets, Roman and Cyrillic. She learned Russian in high school, and her colours for Cyrillic letters are related to her colours for visually similar but not phonetically similar Roman letters (e.g., the colour to the Cyrillic letter "B" is the same as its Roman written counterpart "B" rather than the Roman letter it most sounds like, i.e., "V"). Similarly, Rich et al. (2005) reported the case of synaesthete K.T. who learned Greek as an adult and for whom colours induced by the Greek alphabet are related to colours induced by visually similar Roman letters. Collectively, therefore, these studies suggest that induced synaesthetic colours are related to the visual form of the first grapheme in a word, rather than either the sound or meaning of the word. However, apart from these single-case studies in the literature, to the best of our knowledge, no study has been conducted on a group of linguistic–colour synaesthetes that looked for systematic patterns in induced colours across multiple languages.

As Simner (2007) has noted, colours induced by letters from a secondary language are similar to those induced by letters in the primary language, suggesting a mapping of visual or phonetic form across languages. This further suggests that shared low-level properties, such as grapheme or phonetic form, may be an important determinant in the consistency of colours induced by words across languages. Studies on the acquisition of novel linguistic–colour associations across languages provide some support for this idea. For example, there have been reports of synaesthetes who experience synaesthesia following exposure to languages that they do not understand (Rich et al., 2005), suggesting that lower level properties of the languages (e.g., letters or phonemes) rather than semantics influence the colour experience. On the other hand, a recent study reported by Thierry and Wu (2007) suggests a mechanism by which synaesthetic colours might be mapped onto the primary language or even consistently related across languages without recourse to similarity in visual or phonetic form but, instead, through semantic associations across languages. In a study of (nonsynaesthete) bilinguals, Thierry and Wu found that words presented in a second language are implicitly translated into the primary language. For the purposes of our study, this finding might predict that if colours are induced by the primary language only, then induced colours should be consistent across languages when the meaning of the words are the same, provided the secondary languages are understood. Alternatively, low-level properties of words may nevertheless influence the synaesthetic colour, even if the secondary languages are understood. If so, then the similarity in visual or phonetic form in the words would determine the consistency of the colours induced across languages.

To date, there have been a number of studies assessing linguistic influences on colour associations in English-speaking synaesthetes. Recent research has provided a wealth of data on nonrandom trends in letter– or number–colour pairings across large numbers of synaesthetes (Marks, 1975; Rich et al., 2005; Simner et al., 2005). In general, particular associations are shown to be partially idiosyncratic and may be influenced by top-down mechanisms common to both synaesthetes and nonsynaesthetes (e.g., Marks, 1975; Rich et al., 2005; Simner et al., 2005; Ward, Huckstep, & Tsakanikos, 2006). For example, both groups are more likely to associate colour names with their first letter (e.g., "Y" → yellow) or make semantic links (e.g., "D" → dog → brown; Rich et al., 2005). There are a few cases where learned associations can be traced back to toys or refrigerator magnets of coloured letters (Hancock, 2006; Witthoft & Winawer, 2006); however, there is little evidence to suggest that this is the determining influence of the colour induced by certain stimuli (Rich et al., 2005). In support of the idea that induced colours are idiosyncratic, we found that family members are no more likely to agree on particular linguistic–colour associations than are unrelated synaesthetes (Barnett et al., 2008), suggesting that synaesthetic associations are not based on cultural transmission. However, we did find some consistencies across the population we tested and other populations reported in the literature (e.g., Rich et al., 2005) for some letters (e.g., the letter O usually induces the colour white), suggesting that induced colours are partially idiosyncratic.

Although many studies have found that the colour of a word can often be influenced by its form such that a word can take the colour of its first letter or phoneme (e.g., "market" is the colour of "M"; Baron-Cohen, Harrison, Goldstein, & Wyke, 1993; Baron-Cohen, Wyke, & Binnie, 1987; Marks, 1975; Mills et al., 2002; Ward et al., 2006), the first letter or sound does not always account for the colour induced. For example, form is less likely to predict the colour of a word if that word is part of a linguistic sequence (e.g., numbers, days, months). Here, colours can be unrelated to grapheme content, such that "Monday", for example, has an idiosyncratic colour that is not the same colour as that induced by "M" (Rich et al., 2005; Simner, 2007; Simner et al., 2005). Furthermore, the fact that a concept is often sufficient to induce synaesthesia (Dixon et al., 2000) leads to the question regarding the relative influence of the form of the word or the meaning of the word on synaesthetic colour experiences.

Given the predominance of linguistic inducers in synaesthesia, our aim was to assess the influence of additional languages on synaesthetic colour associations. The specific aim of the current study was, therefore, to investigate the characteristics of linguistic–colour associations in second (or third or fourth) languages in a large sample of linguistic–colour synaesthetes. To that end, we assessed whether colour associations in additional languages were related to the meaning of the word (if so, synaesthetes should report the same colours for words that have the same meaning in different languages) or the form of the word (if so, synaesthetes should report colour associations based on the first letter or sound of the word in different languages). To ensure that colour was not always related to the graphemic or phonemic content of the word in the primary language (i.e., the first letter) we used sequences of words as our stimuli—namely, days, months, and numbers. Such stimuli allowed us to investigate whether consistency of colours induced by words across languages was related to semantics or form without any particular bias from the form of the word in the primary language.

We also investigated whether colour consistency was associated with the age of acquisition of additional languages in order to assess possible influences of a critical period of language acquisition on synaesthetic colour associations. It is not clear whether languages learned later in life can induce synaesthetic colours in a similar manner to the primary language. Gendle (2007), for example, found that a lexical–gustatory synaesthete could readily acquire associations to novel, pronounceable nonwords that he encountered during a testing session (for example the word "cossid" was consistently described as "apple pie filling") and that he maintained these associations over a long term. In contrast, others have found robust synaesthetic associations that were acquired earlier but not later in life. For example, Ward and Simner (2003) describe the experiences of a lexical–gustatory synaesthete, J.I.W., where his synaesthetic tastes are derived predominantly from foods he ate as a child, and he rarely has synaesthetic tastes for foods experienced later in life. In order to assess the role of age of language acquisition on synaesthetic linguistic–colour associations, we compared colour consistency across languages in synaesthetes who had acquired a second language prior to age 5 (i.e., before the written form of the language is accomplished) with synaesthetes who had acquired a second language after the age of 5 (i.e., more likely learned in its written form).

Method

Participants

A total of 21 synaesthetes (18 females and 3 males with a mean age of 46 years ($SD = 15.3$) participated in this study. Prior to this study we established that all participants had linguistic–colour synaesthesia and that their mean test–retest consistency score was 91.89% ($SD = 9.73$; for full details of participant recruitment and consistency testing, see Barnett et al., 2008). Of these synaesthetes, all experienced colour for days of the week, 17 experienced colour for numbers, and 19 experienced colour for months of the year in their primary language.

Materials

Synaesthetes were interviewed about details of any additional languages over the telephone using a questionnaire. The questionnaire (see Appendix) contained detailed questions regarding the second (L2), third (L3), and fourth (L4) language(s) spoken and comprised two sections. The first section included questions about the age of acquisition of the primary and second languages, level of exposure, and degree of language fluency (written and spoken) in each language. The second section assessed the colour associations to word stimuli from three different categories (days of the week, months of the year, and numbers) in each of their additional languages.

Design and procedure

This study is part of a larger project investigating the familial, behavioural, and neurological characteristics of synaesthesia. Prior to this study, participants completed a detailed questionnaire, in writing, regarding their synaesthetic experiences to inducers presented in English (see Barnett et al., 2008). This initial questionnaire was posted to all our participants. For the purposes of the present study, participants were presented with a new questionnaire in which they were first asked to identify their additional languages and to rate their fluency for each additional language using a 5-point scale. A score of 1 indicated minimal fluency, and a score of 5 perfect written and spoken fluency. In the second section of the questionnaire, participants were asked to list, for each language, their colour associations for stimuli from three different categories: numbers (zero to nine, in word not digit form), days of the week (Monday to Friday), and months of the year (January to December). These sequential stimuli are all common inducers in synaesthesia.

For each participant the linguistic–colour associations obtained for stimuli in the primary language (English) were compared with those given for stimuli in L2, L3, and L4. We compared consistency of colour associations for the same stimuli in each additional language using the 0–2 scoring system devised by Rich et al. (2005). For example if the colour "mint green" was experienced for both "Monday" and "lundi", a score of "2" was given indicating the same colour response. A score of "1" was given if only one of the primary or secondary hues was consistent across languages, and a score of "0" represented no colour consistency across languages.

Results

The primary language spoken by this sample of synaesthetes was English, and other languages spoken included French ($N = 7$), German ($N = 2$), Italian ($N = 2$), Irish ($N = 15$), Spanish ($N = 2$), and English ($N = 2$; here Irish was given as the preferred first language although there was no difference in fluency to English). The mean fluency rating for their second language ($N = 21$) was 4 ($SD = 1.06$), and the mean fluency rating for the third language ($N = 7$) was 3.75 ($SD = 0.5$). The 1 participant with a fourth language gave it a fluency rating of 3. In these additional languages all 21 synaesthetes experienced colour for days of the week, 17 experienced colour for numbers, and 19 experienced colour for months of the year.

We first assessed whether the colour induced by sequence words across different languages was related to their meaning or not. Participants' mean colour consistency scores across languages for each of the number (average of 0.87), day (average of 1.04), and month (average of 1.22) stimuli were compared to the potential consistency scores reflecting the same colour (i.e., a score of 2) or a different colour (i.e., a score of 0) induced across languages using nonparametric Wilcoxon signed ranks tests. These analyses revealed that the mean consistency scores for number stimuli across languages were significantly lower than the expected consistency scores if the induced colours were exactly the same ($z = 4.014$, $p < .001$) and significantly greater than the consistency scores expected if the induced colours were completely different across languages ($z = 4.014$, $p < .001$). This pattern of colour consistency scores was also reflected in the scores for the days stimuli ($z = 4.372$, $p < .001$; $z = 4.457$, $p < .001$, in comparison to the expected same or different scores, respectively) and the scores for the months stimuli ($z = 4.014$, $p < .001$; $z = 4.197$, $p < .001$, respectively). These analyses suggest that the colour induced by stimuli are neither consistently the same across different languages nor completely different. In other words, consistency in word meaning across languages did not seem to be the dominant influence in the nature of the colour induced in the group of synaesthetes.

To assess the influence of more low-level perceptual properties of the words across languages (i.e., similarity of the first grapheme or sound) on the consistency of the colour induced we created a set of data based on consistency ratings, with two independent variables for each category of stimuli (numbers, days, and months): similarity of first grapheme and similarity of first sound to the primary language, English. Many of the languages spoken by our synaesthetes share common first letters (graphemes) and sounds (phonemes). Consider the similarities between months of the year in: English (January, February, March, April, May, June, July, August, September, October, November, and December), French (janvier, février, mars, avril, mai, juin, juillet, août, septembre, octobre, novembre, décembre), and German (Januar, Februar, März, April, Mai, Juni, Juli, August, September, Oktober, November, Dezember). In contrast, consider months of the year in Irish (Eanáir, Feabhar, Márta, Aibreán, Bealtaine, Meitheamh, Iúil, Lúnasa, Meán Fómhair, Deireadh Fómhair, Samhain, Nollaig) where the first grapheme and sounds of stimuli are very different to their English counterparts (and indeed all other languages spoken in this sample). Colour consistency data were divided according to whether each stimulus shared the same or different first grapheme to English or the same or different first phoneme to the English counterpart.

The mean colour consistency scores for stimuli (numbers, days, months) in each level of form similarity of first grapheme or first phoneme (same or different) are shown in Figures 1a and 1b, respectively. We conducted separate nonparametric analyses on the following comparisons: element (first grapheme or first phoneme), form similarity of first grapheme or phoneme (same or different), and stimuli (numbers, days, months). The effect of element was significant (Wilcoxon matched pairs test, $z = 2.50$, $p < .02$): stimuli that shared the same first grapheme resulted in more consistent colour scores (mean = 1.162,

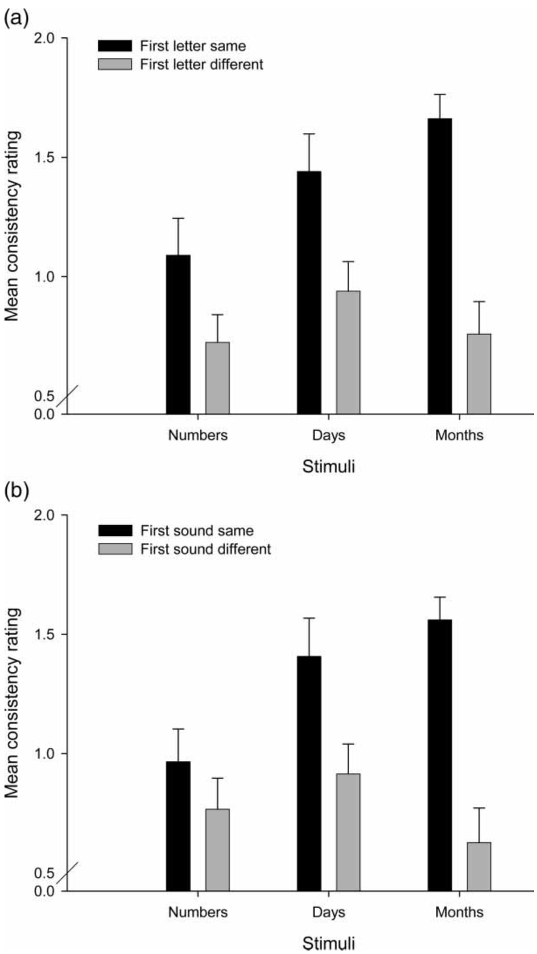

Figure 1. *Colour consistency scores across languages for stimuli (numbers, days, months) where either (a) the first letter (i.e., grapheme) or (b) first syllable sound (i.e., phoneme) for each stimulus category was the same or different to the equivalent stimuli in the primary language (i.e., English). Error bars represent* $\pm$ *1 standard errors of the mean.*

$SE = 0.120$) than stimuli that shared the same first phoneme (mean = 1.108, $SE = 0.120$). There was an effect of form similarity: Wilcoxon matched pairs tests revealed that stimuli beginning with the same first grapheme ($z = 3.70$, $p < .001$) and phoneme ($z = 3.64$, $p < .001$) were more likely to have high colour consistency scores across languages (mean consistency = 1.412, $SE = 0.137$) than stimuli beginning with a different first grapheme or phoneme (mean consistency = 0.858, $SE = 0.133$). There was no overall effect of stimuli (Friedman analysis of variance, ANOVA, $\chi^2_F = 2.66$, $p = .264$). However, given the effects of element and form similarity, we decided to perform more detailed analyses of the effect of stimuli in our data. Using separate Friedman ANOVAs we found no effect of stimuli when the first letter was the same ($N = 16$, $df = 2$, $\chi^2_F = 4.5$, $p = .105$) or when it differed ($N = 13$, $df = 2$, $\chi^2_F = 1.167$, $p = .558$). On the other hand, the effect of stimuli was significant both when the first sound was the same ($N = 16$, $df = 2$, $\chi^2_F = 7.02$, $p < .05$) and when it differed ($N = 13$, $df = 2$, $\chi^2_F = 8.167$, $p < .02$; see Figure 1b). In sum, although synaesthetic colours were more consistent to shared first graphemes than phonemes overall, colours were more consistent across languages when either graphemes or phonemes were shared than when they were different. Moreover, further analyses revealed that phonemes differently affected the degree of colour consistency across stimuli whereas graphemes had the same effect across all days, months, and numbers stimuli.

Given that linguistic–colour associations are thought to be influenced by the same first letter or sound of a word across languages (see also Baron-Cohen et al., 1993; Baron-Cohen et al., 1987; Marks, 1975; Mills et al., 2002; Ward et al., 2006) we decided to conduct a more detailed analysis of the effects of these low-level word properties on colour consistency scores for each of the additional languages. We had 6 (nonsynaesthete) judges assess the similarity between each of the additional languages spoken (French, German, Italian, and Irish) and English. Judges were given a rating scale from 1 (very different) to 5 (identical) and were asked to judge from spoken vocabulary how similar the stimuli were to English. The words from each language were articulated by a native speaker, and the judges were all native English speakers. Two ratings were given based on the sound of the first letter as an alphabetic unit (e.g., the letter C is pronounced /si:/ in English but /se/ in French) and the sound of the first phoneme separately (e.g., for "Monday" in English and French this would be /m/ and /l/, respectively). Ratings were obtained for numbers (zero to nine), days of the week (Monday to Friday), and months of the year (January to December).

Rating similarities between judges across the languages are shown in Table 1. Interrater reliability was calculated across languages using Kendal's coefficient of concordance. We found a high degree of interrater reliability for both judgements based on the sound of the first letter ($n = 6$, $df = 3$, $W = 0.733$, $\chi^2 = 13.20$, $p < .005$) and those based on the sound of the first syllable ($W = 0.678$, $\chi^2 = 12.20$, $p < .007$). These similarity ratings to the sound of the first letter or the phoneme were highly correlated (Spearman $r = .998$, $p < .01$) across languages.

We conducted three separate analyses on the similarity ratings across judges based on either the first letter sound or the first phoneme. These analyses were conducted to assess whether there were any differences in the similarity ratings between the elements (sound of first letter, sound of first phoneme), or the languages (French, German, Italian, Irish), and, finally, the stimuli (numbers, days, months). A Wilcoxon matched pairs test revealed a significant effect of element ($z = 8.438$, $p < .027$) with the sound of the first letter as an alphabetic unit (mean = 2.790, $SE = 0.120$) being rated as more similar to English than the sound of the first phoneme (mean = 2.511, $SE = 0.117$). Using a Friedman ANOVA we found a significant effect of language for both the sound of the first letters ($\chi^2_F = 13.20$, $p < .01$) and phonemes ($\chi^2_F = 12.2$, $p < .01$): overall, the main effect of language was due to judges rating Irish (mean = 1.690, $SE = 0.085$) as being less similar to English than French (mean = 3.048, $SE = 0.167$), German (mean = 3.060, $SE = 0.18$), or Italian (mean = 2.804, $SE = 0.113$). A Friedman ANOVA also revealed a significant effect of stimuli ($\chi^2_F = 12.00$, $p < .01$). Wilcoxon matched pairs tests found that this main effect of stimuli was due to greater similarity for month stimuli (mean = 3.462, $SE = 0.117$) across languages than either numbers (mean = 2.650, $SE = 0.176$; $p < .05$) or days (mean = 1.839, $SE = 0.123$; $p < .05$), and greater similarity for number stimuli than days ($p < .05$).

We then conducted a correlational analysis between the similarity ratings of first-letter sounds and phonemes across languages from the independent judges and the corresponding colour

Table 1. *Similarity of each language to English for first-letter sound and first-syllable sound*

		Language				
Similarity		*French*	*German*	*Italian*	*Irish*	*Average*
Sound of first letter	Numbers	3.28 (0.25)	2.60 (0.35)	3.15 (0.34)	2.27 (0.27)	2.83 (0.30)
	Days	1.86 (0.42)	3.00 (0.30)	1.67 (0.22)	1.21 (0.06)	1.94 (0.25)
	Months	4.51 (0.18)	4.08 (0.26)	4.15 (0.22)	1.69 (0.13)	3.61 (0.19)
	Average	3.22 (0.28)	3.23 (0.30)	2.99 (0.26)	1.73 (0.15)	2.79 (0.25)
Sound of first phoneme	Numbers	2.83 (.027)	2.28 (0.29)	2.58 (0.32)	2.20 (0.31)	2.47 (0.32)
	Days	1.71 (0.36)	2.38 (0.35)	1.62 (0.25)	1.26 (0.16)	1.74 (0.26)
	Months	4.08 (0.16)	4.01 (0.21)	3.65 (0.23)	1.50 (0.16)	3.31 (0.22)
	Average	2.88 (0.26)	2.89 (0.28)	2.62 (0.27)	1.65 (0.21)	2.51 (0.19)

Note: A rating of 5 indicates highly similar whereas a rating of 1 indicates not at all similar. 1 standard error of the mean is shown in parentheses.

consistency scores from the synaesthetes. For the similarity scores to the sound of the first letter as an alphabetic unit we failed to find evidence that these similarity ratings correlated with the colour consistency scores (Spearman $r = 0.400$, $p = .60$). Likewise, we failed to find evidence that the similarity ratings to the first phoneme correlated with the colour consistency scores across languages (Spearman $r = .400$, $p = .60$). In other words, similarities across languages based on low-level properties such as the sound of the first letter or the first phoneme was not the dominant influencing factor on the nature of the colour induced. These results, taken together with the results described above of higher colour consistency when the first grapheme is shared across languages, suggests that visual rather than phonetic form has a greater influence on the nature of the colour induced.

The mean age of language acquisition for L2 in this group of synaesthetes was 6.9 years (range 0 to 19, $SD = 5.6$ years). The mean age of language acquisition for L3 was 10.2 years (range 3 to 12, $SD = 4.2$ years). One individual learned a fourth language at the age of 22. To assess whether age of language acquisition might affect consistency of linguistic–colour associations we divided participants into two groups based on the age of acquisition of additional languages. Group 1 consisted of individuals where L2, L3, or L4 was acquired before the age of 5, and Group 2 included individuals who acquired additional languages after the age of 5 (the age at which children begin formal literacy instruction and acquire proficient reading and written language skills). The means and standard errors of colour consistency ratings for each group across each type of stimulus are plotted in Figure 2.

To assess the effects of age of language acquisition (AoLA) on colour associations for stimuli in additional languages we conducted a Mann–Whitney U test on the mean consistency scores across the two groups (i.e., those that acquired their additional languages before or after the age of 5). We failed to find evidence for an effect of AoLA ($U = 91.5$, $z = -0.094$, $p = .925$). Because of the effect of stimuli observed in our initial analyses, we wondered whether this effect would also emerge for each of the different AoLA groups. Using separate Freidman ANOVAs we found no main effect of stimuli on the group of participants who acquired their additional languages before the age of 5 ($N = 12$, $df = 2$, $\chi^2_F = 0.884$, $p = .642$). However, the effect of stimuli approached significance for the group who acquired their additional languages after the age of 5 ($N = 9$, $df = 2$, $\chi^2_F = 4.67$, $p = .096$): as shown in Figure 2, the colour consistency scores were higher for months than for numbers or days with little evidence of a difference in colour consistency scores between numbers and days.

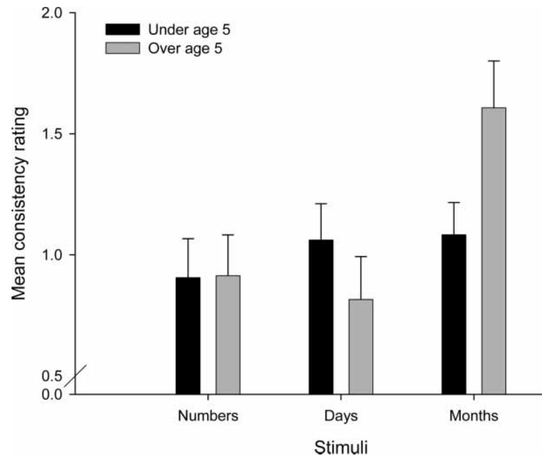

Figure 2. *Colour consistency scores for each group (language acquired before or after the age of 5 years) across each stimulus type (numbers, days, months). A score of 2 represents complete colour consistency across languages, and a score of 0 indicates that the colours were unrelated across languages. Error bars represent ± 1 standard errors of the mean.*

Discussion

Synaesthesia is neurodevelopmental and runs in families (Barnett et al., 2008; Baron-Cohen, Burt, Smith-Laittan, Harrison, & Bolton, 1996; Galton, 1883; Rich et al., 2005; Ward & Simner, 2003). Given the predominance of linguistic inducers in synaesthesia, we wished to assess the influence of additional languages on synaesthetic colour associations. Specifically, the aim of the current study was to determine whether colours induced by sequence words in additional languages are related to similarities to the primary language (i.e., English) in either the grapheme or phoneme form of the word or in the word meaning. In a group of bi- and trilingual synaesthetes, we found that colours induced by days, numbers, and months of the year stimuli were not completely consistent across languages. Instead, our data show that the colour of a stimulus is more likely to be predicted by commonalities in form across languages, particularly related to the visual properties of the word stimuli. Indeed, colour associations were not consistently related to the phonetic similarities across languages. We conducted a detailed analysis of the similarities in the sound of either the first letter (as an alphabetic unit) or first phoneme of words between English and other languages and found that these similarities did not seem to be related to the degree of consistency in the colours induced by these words.

If the visual form of the word, according to our data, has more of an influencing effect on the nature of the colour induced, then we predicted that colours induced by languages acquired after the age of 5 (i.e., the age at which the relationship between letters, words, and their sounds begin to be associated; e.g., Ehri, 1996; Frith, 1985) may be more consistently related to visual similarities (i.e., written forms) than would colours induced by languages acquired earlier on in life. Although we found no overall effects of age of language acquisition on colour consistency effects we did find that colour consistency was affected by the type of word sequence stimuli that induce synaesthesia and the age of acquisition of additional languages: synaesthetes who learned languages after the age of 5 years were marginally more likely to have more consistent colours for months across languages than for either numbers or days than were synaesthetes who learned their secondary languages before the age of 5. Thus, whilst numbers and days tended to induce a colour that is unique to each language, months were somewhat more likely to induce a consistent colour across languages when those languages were acquired after the age of 5.

It is interesting to note that months of the year are also acquired later on in life than days of the week or numbers (Rich et al., 2005; Simner, 2007) and are therefore more likely to be learned in their written form. For example, Rich et al. (2005) reported that the weekday sequence is learned at an earlier age in Australian national schools than the months of the year sequence. Also, the acquisition of counting sequences begins early; 11-month-old children can discriminate decreasing from increasing sequences of numbers (Brannon, 2002), and most children can count 10 objects by 3 years of age (Siegler, Deloache, & Eisenberg, 2003), while the ability to name all 26 letters of the alphabet is not usually present until the age of 6 (Treiman, Tincoff, Rodriquez, Mouzaki, & Francis, 1998). Likewise, days of the week are learned earlier than the months of the year (Freidman, 2005). As such, it may be the case that months induce a colour that is related to the colour induced by the first visual grapheme, as this is the most likely form in which these words are learned. Indeed, the percentage overlap between words beginning with the same first grapheme is much higher for months of the year (78.3%) than it is for either numbers (42%) or days of the week (22.8%). These two observations—that is, the differences in the overlap of low-level visual properties across the stimulus categories and the emerging differences in colour consistency for stimuli more likely to be acquired in their written form—suggest that if the word was initially encountered in a written form then the visual structure (i.e., grapheme shape) has more of an influence on the nature of the induced colour. This proposal is also consistent with the single case studies mentioned previously where the written (i.e., visual) properties of the word largely determined the colour of the concurrent (see e.g., Cytowic, 1993; Mills et al., 2002).

It has previously been reported that the colour induced by the first letter or initial vowel in a word may be the determining factor in the overall colour of a word (Baron-Cohen et al., 1993; Baron-Cohen et al., 1987; Marks, 1975; Mills et al., 2002; Ward et al., 2006). In only rare cases are general whole words uniquely coloured (Baron-Cohen et al., 1987). As an exception, it has been reported that colour for stimuli that form part of a sequence such as days are less likely to be predicted by their first letter or sound (Rich et al., 2005; Simner, 2007; Simner et al., 2005). Our results are in accordance with those of Rich et al. (2005) in that synaesthetic colours induced by days of the week were less likely to be predicted by similarities in the initial letter across languages than those induced by months of the year. We confirmed this finding by comparing the colours induced by single letters and those induced by the first letter of the day stimuli in our entire sample of 64 synaesthetes that we have previously reported (see Barnett et al., 2008).

Interestingly, data from the Irish population suggest that if a person is predisposed to have linguistic–colour synaesthesia, the ability to acquire new linguistic–colour associations in additional languages remains plastic (Mills et al., 2002). According to our data here, new linguistic–colour associations can be acquired rapidly, and most likely in an implicit manner, even after the age of 5. However, our findings do not suggest that colours are consistent across languages when the meaning is the same. Instead, at least for sequence words, it seems that colours induced by newly acquired languages are largely related to the low-level (mainly visual) properties of the new stimuli and do not necessarily reflect the semantic associations between the colours and stimuli from the primary language. Thus, knowledge or understanding of languages outside the primary language may not be necessary for colour to be induced by those words (see e.g., Gendle, 2007). Indeed, Simner (2007) has suggested that the commonality of colours induced across languages may be due to a cross-linguistic mapping of graphemes to the primary language. To assess the extent of the role of semantic or more perceptual properties of words on induced synaesthetic colours, it would be interesting to follow this study with one involving multiple synaesthete participants fluent in languages that vary in grapheme form such as Hebrew or Cyrillic. Furthermore, the subtle influences of semantic knowledge on linguistic–colour synaesthesia may be revealed by comparing the consistency of colours induced by words in secondary languages across groups of synaesthetes who are either fluent or not at all fluent in these languages.

Previous findings from a sample of English-speaking synaesthetes have suggested that sequences such as days and months are more likely to have a unique colour that is not based on the colour of the first letter than are words from nonsequential categories such as place names and people's names (Rich et al., 2005). Our study allowed us to compare the effects of grapheme or phoneme similarity in sequence words across languages, and the inclusion of 15 Irish speakers in this data set made it possible to distinguish the effects of the sound of either the first letter or phoneme versus meaning on linguistic–colour associations across languages. Ireland is unique in that the majority of the population are exposed to Irish through formal schooling (Hickey, 1997), and the Irish language is not similar to English or most other European languages. In other words, comparing same and different first grapheme or phoneme effects between months for English and French data sets, for example, would not have enabled meaningful comparisons as the two languages share the same first graphemes and have similar sounds for all 12 months. As it turned out, the overall colour consistency scores did not correlate with the similarity scores for sounds across languages, either for the first letter or for the phoneme. Therefore, similarity in auditory form across languages is unlikely to be the main contributing factor to the nature of the colours induced by stimuli across languages.

Colour consistency for some stimulus types may be difficult to predict due to the different ways in which the stimuli can be represented. For example, number stimuli can be characterized by multiple visual representations: Numerosity may be represented as "one", "1", and".", and so on (Ward & Sagiv, 2007) or the number "1" can be represented as a digit or word (Palmeri, Blake, Marois, Flanery, & Whetsell, 2002). Moreover, number stimuli can induce different types of synaesthesia. For example, synaesthetes often report experiencing stimuli such as numbers and days of the week in spatial arrangement around their body (Smilek, Callejas, Dixon, & Merikle, 2007). Also, Simner and Hubbard (2006) report a case of a synaesthete with coloured graphemes and ordinal linguistic personification (the association of animate qualities such as gender or personality to letters, numbers, or days). Simner and Hubbard (2006) suggest that because the ability to understand personality traits occurs later than the ability to understand ordinal relations (see Gnepp & Chilamkurti, 1988) that the boundaries of a putative critical period in synaesthesia extend into later childhood/adolescence. Specifically, they suggest that the synaesthetic associations that characterize ordinal linguistic personification emerge after the age of 5 to 8 years. Our data suggest that there may be a critical period within which different mechanisms are involved in determining the nature of the colour associations that develop. Colours induced by sequence words learned in their visual form—that is, words learned later on in life or after the age of 5—are somewhat more likely to be determined by the visual properties of the words than by the phonetic properties. Our findings also suggest that once these associations are in place the formation of new colour associations in additional languages is not subject to a defined critical period. Linguistic stimuli are the predominant inducers of synaesthetic experiences, and the current data suggest that the acquisition of new colour associations in synaesthesia is relatively plastic in that synaesthetes retain the ability to form new associations throughout the lifespan. The extent to which the ability to generate colour associations to novel stimuli depends on either low-level similarities to the primary language or on a critical period during which novel associations are more readily acquired is not yet known and remains an interesting topic for future research.

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APPENDIX: RELEVANT QUESTIONNAIRE ITEMS

A1. Primary language

What was the first language you learned as a child?

At what age did you learn this language?

How much exposure have you had to this language, i.e., did your parents speak it at home; were you schooled in it; do you use it daily; are you or have you lived in the country in which this language is spoken?

Have you formally studied this language?

If yes, to what level?

☐ Secondary school (Inter/Junior cert level)
☐ Secondary school (Leaving certificate)
☐ University

How would you rate your fluency in this language?

☐ 5 = very fluent
☐ 4
☐ 3
☐ 2
☐ 1 = not able to understand/speak at all

A2. Second language

Do you speak any other language(s), and if so what language(s)?

How much exposure have you had to this language(s), i.e., did your parents speak it at home; were you schooled in it; do you use it daily; are you or have you lived in the country in which this language is spoken?

Have you formally studied this language(s)?

If yes, to what level?

☐ Secondary school (Inter/Junior cert level)
☐ Secondary school (Leaving certificate)
☐ University

How would you rate your fluency in this language(s)?

☐ 5 = very fluent
☐ 4
☐ 3
☐ 2
☐ 1 = not able to understand/speak at all

Irish citizens only

How would you rate your fluency in Irish?

☐ 5 = very fluent
☐ 4
☐ 3
☐ 2
☐ 1 = not able to understand/speak at all

To what level did you study Irish?

☐ Primary school
☐ Secondary school (Inter/Junior cert level)
☐ Secondary school (Leaving certificate)
☐ University

A3. Characteristics of synaesthesia

Do you experience synaesthesia in more than one language?

If yes, what languages?

Is your synaesthesia stronger (more intense) in some languages than others?

If yes, rank your languages in order of intensity of synaesthesia.