Synaesthesia is linked to more vivid and detailed content of autobiographical memories and less fading of childhood memories

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Synaesthesia is linked to More Vivid and Detailed Content of Autobiographical Memories and Less Fading of Childhood Memories

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People with synaesthesia have enhanced memory on a wide range of laboratory tests of episodic memory, but very little is known about their real-world memory. This study used a standard measure of autobiographical remembering (the Autobiographical Memory Questionnaire, AMQ) considering four constructs (Recollection, Belief, Impact and Rehearsal) and two time periods (recent memories from adulthood, remote memories from childhood). Synaesthetes reported more Recollection (e.g. sensory detail) and Belief (e.g. confidence) which interacted with time, such that remote memories are reported to be comparatively better preserved in synaesthetes. This cannot be explained by synaesthetes recalling more salient episodes (the groups did not differ in Impact). It suggests instead that childhood memories have a special status in synaesthesia that reflects the different neurodevelopmental trajectory of this group. With regards to Rehearsal, controls tended to report that more recent memories tend to resurface (i.e. adulthood > childhood), but the synaesthetes showed the opposite dissociation (i.e. childhood > adulthood).

Keywords: memory; autobiographical; synaesthesia/synesthesia; recollection; metacognition.

INTRODUCTION

People with synaesthesia have automatic, percept-like experiences triggered by stimuli that don't normally elicit these experiences: for instance, words may have tastes, or numbers may be coloured. Synaesthesia can be reliably detected from childhood, around 6 years (Simner & Bain, 2013), although it may have its roots in neurodevelopmental differences in brain wiring originating in infancy (Maurer & Mondloch, 2006) owing to a genetic component (e.g. Tomson et al., 2011). People with synaesthesia don't just have unusual perceptual experiences: they also appear to have a distinctive cognitive profile. For instance, they have enhanced mental imagery defined in terms of both subjective vividness (Barnett & Newell, 2007) and performance on objective measures (Havlik, Carmichael, & Simner, 2015; Spiller, Jonas, Simner, & Jansari, 2015). They also tend to show enhanced performance on tests of episodic memory (Rothen, Meier, & Ward, 2012). Almost all studies investigating the memory advantage of synaesthetes involves learning and retention of material encountered in experimental settings. Whilst this controlled approach has clear benefits, it limits our theoretical understanding to short retention periods and to simple stimuli rather than the complex multi-dimensional events accumulated and retrieved over a life time of experiences (e.g. Rubin, 2006). The present study aims to address this important gap by considering recollection of autobiographical events from different life periods.

The most famous case of exceptional memory in synaesthesia was that of Shereshevskii, reported by Luria (1968). Shereshevskii's memory was described as having "no distinct limits . . . there was no limit either to the capacity of S.'s memory or the durability of the traces retained" (p. 11). Subsequent research has shown that most synaesthetes do not possess this level of exceptional ability but they do show enhanced memory typically with medium effect sizes (for a review see Rothen et al., 2012). Most research on memory in

synaesthesia has focussed on memory for verbal material (words, numbers, etc.), whether spoken or written, and memory for visual material (shapes, colours, scenes, etc.). It has also focussed mainly on people with grapheme-colour synaesthesia for whom letters, numbers, and words elicit colours. One might expect that, for these synaesthetes, verbal stimuli would be better remembered because they are encoded visually (as colours) as well as verbally/semantically. Whilst this may be a factor, it is unlikely to be the main explanation because synaesthetes show, if anything, an even greater memory advantage for visual stimuli that do not evoke extra sensations including those that are hard to recode verbally such as fractals (e.g. Rothen & Meier, 2010; Ward, Hovard, Jones, & Rothen, 2013). One explanation for this is that (grapheme-colour) synaesthetes have a more 'visual' cognitive style and are able to draw on more finely tuned visual representations that support memory, imagery and perception (Rothen et al., 2012).

The extent to which these putative changes in cognition affect autobiographical memory is unknown, although we can make predictions. The retrieval of autobiographical memories involves a reactivation of sensory (visual, auditory, etc.) and contextual (spatial, temporal, etc.) details that generate a subjective 'reliving' (or 'mental time travel') of that episode (Conway, 2001; Rubin, 2006; Wheeler, Stuss, & Tulving, 1997). As such we predict that synaesthetes will report more vivid and detailed recollective experience, at least for visual/sensory information. This may also underpin confidence and belief in the veracity of the memory, irrespective of whether such confidence is warranted (e.g. Talarico & Rubin, 2007). To some extent these experiential and meta-memory aspects of remembering are dissociable from objective measures of memory performance: for example, disruption of the parietal lobes via brain lesions (Simons, Peers, Mazuz, Berryhill, & Olson, 2010) or brain stimulation (Yazar, Bergstrom, & Simons, 2014) lowers confidence and recollective experience with minimal effects on memory performance.

The present study uses a well-established measure of autobiographical memory, the Autobiographical Memory Questionnaire (AMQ) developed by Rubin and colleagues (e.g. Rubin, Schrauf, & Greenberg, 2003) and known to have good test-retest reliability (Rubin, Schrauf, & Greenberg, 2004). This is based on a much longer tradition of using single cue words (e.g. a noun) to facilitate retrieval of specific episodic memories from one's own personal history (e.g. Robinson, 1976). Having retrieved a suitable memory related to the cue word, the AMQ then asks a series of questions (on a 1-7 scale) probing the content of that memory (e.g. level of emotionality, sensory detail) and aspects of meta-memory (e.g. confidence). The advantage of this method is that it easily lends itself to testing specific comparisons of interest. For instance, one can compare the quality of autobiographical memories elicited by emotional versus neutral cue words (Talarico, Berntsen, & Rubin, 2009), or use the same cue word to probe different periods of life (e.g. childhood versus early adulthood; Rubin & Schulkind, 1997), or to make between-subject comparisons (e.g. to explore the effects of depression or dementia; Fromholt et al., 2003). Of relevance to the present group are findings that individual difference in visual imagery (both high imagery and absence of imagery), are linked to the phenomenological qualities of remembering (e.g. reliving) on the AMQ (Greenberg & Knowlton, 2014).

Our study contrasts autobiographical memories both within-subjects (childhood v. recent adulthood memories) and between-subjects (synaesthetes v. non-synaesthetes), and is based on the latent constructs approach of Fitzgerald and Broadbridge (2013). Fitzgerald and Broadbridge (2013) constructed and evaluated a model of autobiographical memory, using a version of the AMQ, with four conceptually distinct but interacting components. The two main constructs were Recollection (e.g. reliving, visual imagery) and Belief (e.g. willing to testify, really occurred) that correspond, respectively, to memory content and metacognitive judgments. The Belief component also includes the core episodic properties of specificity in

time and place that underpin the metacognitive judgement of distinguishing episodic from semantic memories (also commonly referred to as 'remember' versus 'know', Gardiner, 1988). The remaining two constructs are Impact (e.g. significance of the memory) and Rehearsal (e.g. whether thought the event since either voluntarily or involuntarily). They showed differences amongst these constructs by contrasting different kinds of memory (e.g. earliest childhood memory, very vivid memory). A recent study adopted this approach to examine autobiographical memory qualities of blind participants (Tekcan et al., 2015). To some extent, this is the complementary approach to our own. Whereas blind people lack visual-related qualities in their autobiographical memories, we hypothesize that synaesthetes will have an exuberance of visual and sensory qualities. To explore this further, we also conduct an analysis of the text-based responses to explore the frequency of colour terms (e.g. "green", "red") to describe the memories. We do not have a strong prediction as to whether synaesthetes will show particular differences for recent versus remote memories and this aspect of our study should be regarded as exploratory.

METHODS

Participants

One hundred and eleven volunteers initially participated in this study. Synaesthete participants were recruited through a database belonging to the University of Sussex. All synaesthetes had grapheme-colour synaesthesia (minimally) which was previously assessed by a standard procedure of looking for the stability of colour associations (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007), where a lower score <1.43 is taken as indicative of synaesthesia (Rothen, Seth, Witzel, & Ward, 2013). Controls were collected partly via opportunistic sampling from students and acquaintances and some were recruited via Mechanical Turk, an online participant recruiting site, that has been shown to offer a more

demographically representative sample than obtained via other means (Buhrmester, Kwang, & Gosling, 2011). The control group are a normative sample insofar as we did not screen for the absence of synaesthesia. However, given the rarity of synaesthesia – 1.4% for grapheme colour and around 4.4% including other types (Simner et al., 2006) – this is unlikely to distort the data. In order to match the groups by age, we excluded 9 older synaesthetes and the 10 youngest controls. A further two participants were excluded because they did not comply with the instructions (not producing enough memories specific in time). As such the final sample was comprised of 44 control participants (mean age = 40.4 years, SD=14.5; 25 female), and 40 synaesthetes (mean age = 43.6 years, SD=11.6; 39 female).

The research was approved by the University of Sussex Cross-Schools Science and Technology Research Ethics Committee, and followed standard procedures of informed consent and right to withdraw as laid out in the Declaration of Helsinki.

Materials

There were six neutral cue words (chocolate, train, doctor, snow, vacation, party), two time periods (recent, remote), and 14 AMQ questions for each cue word and time period. The questions, listed below, are taken from previous sources. Eleven of the questions were used by Fitzgerald and Broadbridge (2013), or very closely adapted from their items, and were assigned to their latent constructs accordingly. Three items (Q12, Q13, Q14) were taken from other studies using the AMQ, and were assigned to latent constructs based on conceptual similarity and confirmed by the pattern of correlations. Q12 “own eyes” correlated strongly with Q3 “see” and Q9 “really occurred” and was grouped with the latter under BELIEF. Q13 “out of the blue” correlated strongly with “thought about or discussed” and was classed as REHEARSAL. Q14 “specific details” correlated strongly with both RECOLLECTION items (e.g. Q1-“reliving”, Q5-“emotions”) and BELIEF items (e.g. Q4-“space”, Q7-“time of day”)

and was assigned as RECOLLECTION based on closer conceptual similarity. The questions are as follows but participants were not informed about the latent constructs:

Q1. RECOLLECTION. "As I remember the event, I feel that I travel back in time when it happened as if participating in it again. I feel as if I am **reliving** it." [1=not at all; 7 = As clearly as being in the present]

Q2. RECOLLECTION. "As I remember the event, I can **hear** it in my mind." [1=not at all; 7 = As clearly as being in the present]

Q3. RECOLLECTION. "As I remember the event, I can **see** it in my mind." [1=not at all; 7 = As clearly as being in the present]

Q4. BELIEF. "As I remember the event, I know its **spatial layout**." [1=not at all; 7 = As clearly as being in the present]

Q5. RECOLLECTION. "As I remember the event, I can feel the **emotions** that I felt then." [1=not at all; 7 = As clearly as being in the present]

Q6. REHEARSAL. "Since it happened, I have **thought about or discussed** the event, or both. In other words, it has resurfaced in my mind outside the present study". [1=not at all; 7 = regularly]

Q7. BELIEF. "As I remember the event, I am aware of the **time of day**." [1=not at all; 7 = As clearly as being in the present]

Q8. BELIEF. "Would you be confident enough in your memory of the event to **testify** in a court of law". [1=not at all; 7 = very confident]

Q9. BELIEF. "I believe the event in my memory **really occurred** in the way I remember it and that I have not imagined or fabricated anything that did not occur." [1=completely imaginary; 7 = completely real]

Q10. IMPACT. "The memory is **significant** or has **consequences** for my life, and influences my behaviour, thoughts or feelings in noticeable ways." [1=not at all; 7 = As much as any memory]

Q11. BELIEF. "As I remember the event, it comes to me in words or pictures as a **coherent story or episode** and not as an isolated fact, observation, or static scene." [1=not at all; 7 = completely]

Q12. BELIEF. "While remembering the event, I feel that I see it out of **my own eyes** rather than that of an outside observer." [1=not at all; 7 = completely]

Q13. REHEARSAL. "The memory has previously come to me '**out of the blue**' without me trying to think of it" [1=not at all; 7 = more than for any other memory]

Q14. RECOLLECTION. "I can imagine many **specific details** vividly, such as what someone was wearing, what song was playing in the background, etc." [1=not at all; 7 = As clearly as being in the present]

Procedure

All participants completed the AMQ as an online survey hosted on Qualtrics, with the survey taking approximately 30 minutes in total. The recall of remote and recent memories were blocked (in that order), and the order of the six cue words were randomised within each block. The order of the 14 questions for each cue word was fixed, and participants were forced to answer each question before moving on. The cue word was presented in bold upper case (e.g. "Cue word: **CHOCOLATE**") followed by a detailed description of what had to be recalled:

> "*Instructions*: Look at the cue word in bold above. Please think of a strong memory that comes to mind when viewing the cue word that occurred [during early childhood (0-12 years) / occurred between three months and three years ago]*. It must be a

specific event (e.g. “That time when I spilled coffee on Bob on the train to Birmingham”) rather than a generic event or collection of events (e.g. “Commuting to London for a year when I was 18”). Take a minute to complete the memory in your mind so that you have remembered the greatest amount of intensity and content possible. Then write a summary of the memory in 2-3 sentences. Next read each item carefully and select the number that most closely matches your perspective.” * = specified as appropriate.

They were given a text box to write down a summary of the memory and another box in which they were asked to state how long ago, or when, the event took place. These questions were included to facilitate the retrieval process of the participant and it also enabled us to ensure that the participant had complied with the instructions. Any responses not meeting the criteria (i.e. not episodic, not from the requested time period) were excluded from the analysis.

Results

A small number of memories were excluded from the analysis: 2.9% (N=14) from synaesthetes and 6.8% (N=36) from controls. We first consider responses to the AMQ, as this is the primary measure of interest, and we then consider a more exploratory analysis of the text-based responses.

AMQ

The AMQ responses were averaged across cue words and averaged into the four pre-defined constructs: Recollection, Belief, Rehearsal, and Impact. Thus, for each memory process a 2x2 mixed ANOVA was conducted contrasting group (synaesthete, control) against time period (remote, recent) with a Bonferroni corrected $\alpha<.05/4$. The results are summarised in Figure 1. Overall, ratings tended to be mid-to-high for Recollection and Belief: that is, the

retrieved memories had generally high levels of content and were deemed veridical. Ratings for Rehearsal and Impact were low: that is, the memories were generally of a more trivial nature and not regularly thought about. Responses to individual questions are presented in Table 1. Whilst we did not analyse each question separately, we report it here for completeness and to demonstrate that the overall pattern of results conveyed by the construct means are reflected by individual items.

INSERT FIGURES 1 AND TABLE 1 ABOUT HERE

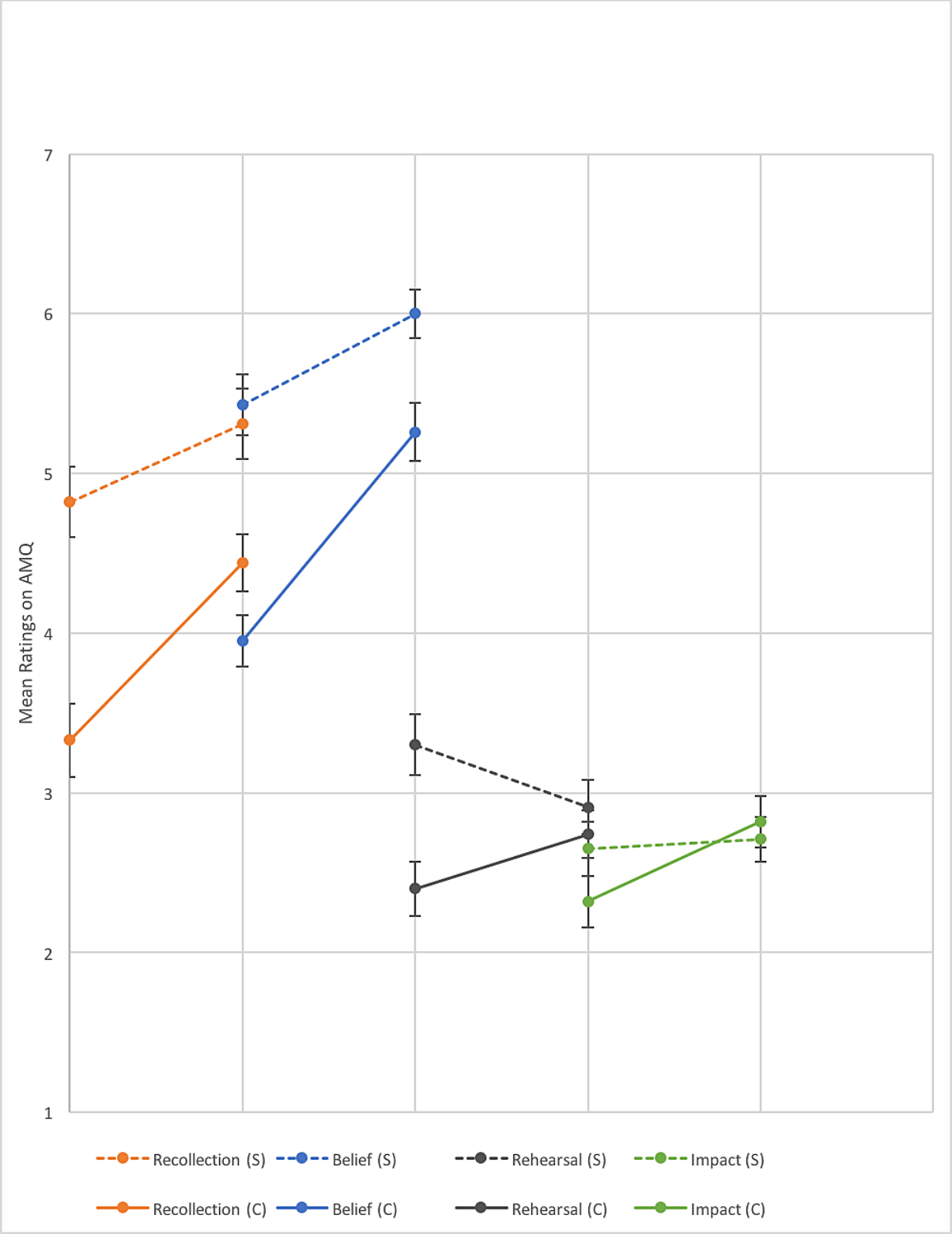

Figure 1: The AMQ uses a 1-7 scale and the questions were divided into four different constructs (Recollection , Belief, Rehearsal, Impact). The dotted bars are from synaesthetes and the solid lines are controls. The left side of each scale remote memories (0-12 years old) and the right side is recent memories (3 months to 3 years ago). Error bars show 1 SEM.

Table 1: Mean scores (1-7 scale), S.D. in parentheses, for individual questions, averaged across cue items and time periods, for remote and recent memories recalled be synaesthetes and controls.

		Synaesthetes		**Controls**	
Subscale	**Question**	**Remote**	**Recent**	**Remote**	**Recent**
Recollection	*Details*	4.31 (1.10)	4.97 (1.41)	2.93 (1.35)	4.32 (1.47)
	Hear	3.80 (1.44)	4.77 (1.38)	2.83 (1.43)	3.93 (1.65)
	See	5.72 (0.81)	6.17 (0.95)	4.12 (1.22)	5.19 (1.29)
	Relive	5.05 (1.15)	5.67 (1.17)	3.38 (1.41)	4.63 (1.35)
	Emotion	5.24 (1.10)	5.65 (1.14)	3.80 (1.38)	4.84 (1.30)
Belief	*Spatial*	5.43 (1.13)	6.16 (0.99)	3.54 (1.28)	4.99 (1.41)
	Coherent	5.09 (1.24)	5.93 (1.14)	3.76 (1.31)	5.21 (1.20)
	Time	4.90 (1.18)	5.90 (1.06)	3.61 (1.31)	4.99 (1.23)
	Testify	5.20 (1.24)	6.02 (1.14)	3.59 (1.55)	5.38 (1.34)
	Own eyes	5.80 (1.12)	6.28 (0.94)	4.37 (1.43)	5.63 (1.26)
	Really occurred	6.23 (0.81)	6.61 (0.60)	5.50 (1.10)	6.35 (0.81)
Rehearsal	*Thought about*	3.36 (1.06)	3.10 (1.13)	2.63 (1.08)	3.05 (1.22)
	Out of blue	3.24 (1.21)	2.81 (1.25)	2.27 (0.97)	2.59 (1.20)
Impact	*Significant*	2.65 (1.36)	2.78 (1.38)	2.41 (1.26)	2.97 (1.67)

For Recollection, there was a significant effect of group such that synaesthetes reported more recollective experience ($F(1,82)=24.794$, $p<.001$, $\eta_p^2=.232$). There was a significant effect of time period such that recent events have more recollective experience than remote events ($F(1,82)=97.926$, $p<.001$. $\eta_p^2=.544$), and a significant interaction ($F(1,82)=8.977$, $p=.004$, $\eta_p^2=.099$) such that the effect of time on memory was greater for controls than synaesthetes. To put it another way, remote memories from childhood are better preserved by synaesthetes.

The same pattern was observed for the Belief component. There was a significant effect of group such that synaesthetes reported more belief in their memories ($F(1,82)=30.205$, $p<.001$, $\eta_p^2=.269$). There was a significant effect of time period such that recent events are linked to stronger beliefs than remote events ($F(1,82)=142.087$, $p<.001$, $\eta_p^2=.634$), and a significant interaction such that the effect of time on memory was greater for controls than synaesthetes ($F(1,82)=15.104$, $p<.001$, $\eta_p^2=.156$). Again, remote and recent memories appear to be more similar to each other for synaesthetes than they are controls.

For Rehearsal, the pattern was different. There was no effect of time period ($F(1,82)=0.021$, $p=.885$, $\eta_p^2=.000$), and a significant effect of group that did not survive Bonferroni correction ($F(1,82)=5.074$, $p=.027$, $\eta_p^2=.058$). Nevertheless there was an interaction between group and time period ($F(1,82)=14.047$, $p<.001$, $\eta_p^2=.146$). The latter is qualitatively different from the previous interactions in that the two groups show effects in different directions: synaesthetes report more rehearsal for remote over recent memories ($t(39)=2.319$, $p=.026$) but controls report the reverse pattern of more rehearsal for recent over remote memories ($t(43)=3.038$, $p=.004$).

For Impact, the pattern of results was different again. There was no significant effect of group ($F(1,82)=0.013$, $p=.911$, $\eta_p^2=.000$). There was a significant effect of time period such

that recent memories were rated as more consequential ($F(1,82)=7.935$, $p=.006$, $\eta_p^2=.088$), but no interaction between time and group ($F(1,82)=3.065$, $p=.084$, $\eta_p^2=.036$).

Given that recent and remote time periods had differential effects in synaesthetes and controls, we wondered whether this was generally true across all participants or whether it may be driven by certain age groups within our samples (given that a childhood memory for an older person is more distant than for someone younger). Adding age as a covariate in the previous analyses had only one effect: age was a significant covariate on the Impact ratings ($F(1,82)=7.869$, $p=.006$, $\eta_p^2=.089$). Thus older people tended to rate their autobiographical memories (both remote and recent) as more significant and consequential than younger people. However, this was equally true of synaesthetes and controls (mean Impact of young and old synaesthetes = 2.3 [0.9] and 3.2 [1.5]; mean Impact of young and old controls = 2.3 [1.0] and 3.1[1.6]; based on a median split by age, SDs in brackets). Age exerted no effects or interactions in any other analysis (all p's>.100). Thus, we conclude that the effects of synaesthesia on recent and remote autobiographical memories are not driven by one particular age demographic within our heterogeneous sample.

It is also possible that the synaesthetes' remote memories appear to be better preserved because they are drawn from relatively later in life compared to the controls. However, this is not the case and, in fact, the reverse is true. The remote memories of synaesthetes tend to be drawn from earlier in childhood (mean age of 7.60 years, S.D.=1.12) than controls (mean age of 9.13 years, S.D.=2.29; $t(63.68)=3.819$, $p<.001$, correcting for unequal variances). This suggests that synaesthetes remote autobiographical memories are subjectively richer despite being drawn somewhat earlier from childhood.

Text-based Analyses

The present study was not specifically designed to examine the text-based data as we only asked for brief descriptions whereas previous studies employing this method typically ask for 'as much detail as you can' (e.g. Bauer, Hattenschwiler, & Larkina, 2016). Nevertheless, we conducted a preliminary investigation of the text-based descriptions using both exploratory and planned analyses. The exploratory analyses consisted of the generation of 'word clouds' in which frequently occurring words in the corpora (relative to linguistic frequency) are highlighted. This is presented in Supplementary Material. For the planned analysis, we compared the summed frequency of eleven 'basic' colour terms (from Berlin & Kay, 1969) between groups and time periods. The terms being: white, black, grey, red, yellow, green, blue, purple, pink, orange and brown, We also did the same for two generic words linked to memory ("remember" and "time") that appeared frequently in the corpora, and that we did not expect to be linked to synaesthesia. The results are summarised in Figure 2. For colour terms, there was a main effect of group ($F(1,82)=15.353$, $p<.001$, $\eta_p^2=.158$) with synaesthetes reporting more 'colourful' memories. It is to be noted that the colour terms were always used to denote real objects (e.g. a red dress worn at a party) rather than synaesthetic experiences themselves. There was also a main effect of time period (remote>recent, $F(1,82)=8.444$, $p=.005$, $\eta_p^2=.093$) but no interaction ($F(1,82)=0.417$, $p=.520$, $\eta_p^2=.005$). The word "remember" was more frequently used for describing remote memories ($F(1,82)=30.089$, $p<.001$, $\eta_p^2=.268$) but didn't differ by group ($F(1,82)=0.031$, $p=.860$, $\eta_p^2=.000$) or interact with group ($F(1,82)=0.057$, $p=.812$, $\eta_p^2=.001$). The word "time" did not differ by either recency ($F(1,82)=0.951$, $p=.332$, $\eta_p^2=.011$) or group ($F(1,82)=0.057$, $p=.812$, $\eta_p^2=.001$) and showed no interaction ($F(1,82)=1.335$, $p=.251$, $\eta_p^2=.016$).

INSERT FIGURE 2 ABOUT HERE

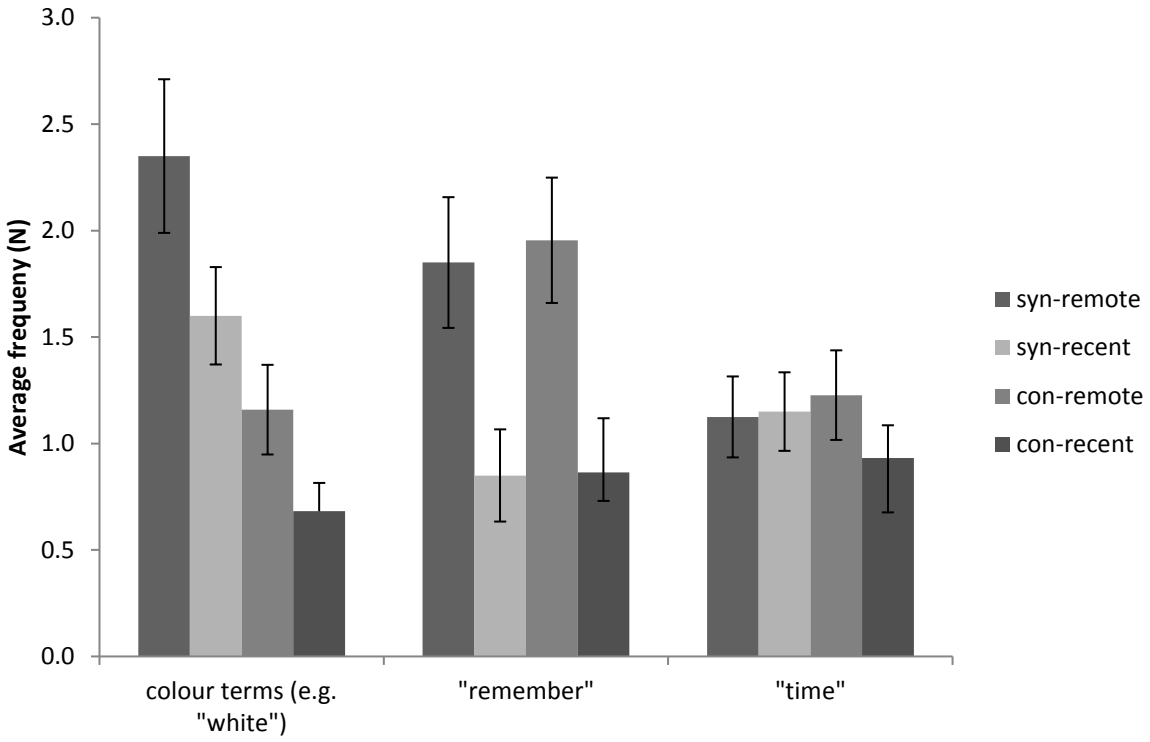

Figure 2: Frequency counts (average per participant) from the brief text-based descriptions for colour terms (e.g. “white”), and the words “remember” and “time”. Error bars show 1 S.E.M.

Discussion

The aim of this study was to determine how the known memory advantage of individuals with synaesthesia for laboratory-based episodic memory tests manifests itself in autobiographical memory. Our hypothesis was that the autobiographical memory content of people with synaesthesia will contain high levels of recollective experience, including sensory details. This was expected given previous findings of elevated levels of vivid mental imagery in this group (Spiller et al., 2015) in addition to the objective benefits linked to memory (Rothen et al., 2012). This hypothesis was supported. Similarly and relatedly, synaesthetes reported higher levels of belief in the veracity of their memories. Although memory advantages in

synaesthesia have been documented before, the present study differs from previous ones by showing directly that it extends to qualitative aspects of remembering (recollective detail and metacognitive beliefs). Moreover, what is novel and theoretically important is the observation that both Recollection and Belief show differing levels of fading over time between the groups. Both groups report higher levels of Recollection and Belief for recent memories over remote memories from childhood. However, this drop-off is far more pronounced in the controls than the synaesthetes. In other words, synaesthetes appear to be better able to preserve/retrieve the subjective qualities of their more distant memories in order to relive them in the present.

Other aspects of the AMQ are relevant for explaining why this might be. First of all, we can rule out the possibility that the retrieved remote memories of synaesthetes were more significant or consequential: the Impact question did not differ across groups. Secondly, nor is it the case that the remote memory advantage was driven by one particular age group. Age had no effect on Recollection or Belief. The relative advantage of remote memories could possibly be explained by synaesthetes retrieving remote memories more often than controls, with controls showing a pattern in the reverse direction. That is, remote memories of synaesthetes might have greater Recollection and Belief because they are rehearsed more. However, the direction of cause and effect between Rehearsal and Recollection/Belief cannot be easily ascertained. It may be that remote memories are subjectively vivid and detailed because they are re-experienced more often, but it could equally be the case that remote memories are retrieved more often because they are subjectively vivid and detailed. The latter explanation is backed up by the fact that synaesthetes are significantly more likely to retrieve remote memories involuntarily (appearing 'out of the blue' Q13) as well as voluntarily.

Our findings can be compared with previous research on the recall of autiobiographical memories from childhood and adulthood. With regards to perceptual qualities of memories, previous findings have been inconsistent with regards to whether early childhood memories

have more or less of this quality. Howes, Siegel, and Brown (1993) reported more colour and spatial detail in very early (<2 years) memories contrasted with later ones. West and Bauer (1999), however, did not find this effect in ratings of narratives for 'imaginal detail' (including colour) for memories earlier versus later than 7 years (although a trend for more imaginal detail was found for earlier memories in males). Our finding, based on colour terms, is consistent with Howes et al. (1993) for both synaesthetes and controls. However, in terms of the AMQ, childhood memories were rated as having less sensory qualities (e.g. on 'see' and 'hear' questions). This points to a possible dissociation between factual knowledge of sensory content (in early memories) versus re-experiencing the sensory aspects of an event (in recent memories). With regards to perspective, our results suggest that whereas recent memories are remembered in a first-person perspective, childhood memories may have a mix of first- and third-person perspectives (see also West & Bauer, 1999). Future research on autobiographical memory in synaesthetes should directly contrast the AMQ-type approach with an analysis of narrative content. The latter approach typically instructs participants to generate as much detail as they can (e.g. Bauer, et al., 2016) whereas we asked participants to briefly describe the memory (with the aim of ascertaining that it was a valid memory rather than analysing its content).

To date, very little is known about the cognitive profile of children with synaesthesia (but see Green & Goswami, 2008). However, we do know that the synaesthetic associations (at least for grapheme-colour) become gradually more stable at the age of 6-10 years as literacy itself develops (Simner & Bain, 2013). Rather than arguing that synaesthetes are merely people with good memory we, and others, suggest that there are fundamental differences in the childhood brain of synaesthetes (Maurer & Mondloch, 2006). These differences affect not only memory but affect other aspects of cognition such as perceptual ability/sensitivity (Ward et al., 2017; Ward, Rothen, Chang, & Kanai, in press) and mental imagery (Mealor, Simner, Rothen,

Carmichael, & Ward, 2016). For instance, using a computational model we have shown that synaesthesia can emerge from changes in sensory sensitivity or increased plasticity in the model even when the model is not trained to make particular associations (Shriki, Sadeh, & Ward, 2016). Whatever the nature of the developmental differences in cognition and brain development, our research suggests that it not only leads to the emergence of synaesthesia but may also lead to more stable and detailed autobiographical memories that are relatively protected throughout the lifespan.

The present research also paves the way for examining objective measures of autobiographical memory in synaesthetes, and also generates novel predictions for assessing childhood memories both in child synaesthetes and adult synaesthetes. However, it should be noted that it is theoretically possible to have subjectively rich autobiographical remembering that does not lead to enhanced objective performance (e.g. Talarico & Rubin, 2007). The only previous study to have explored autobiographical recollection in synaesthetes was based on sequence-space synaesthetes who visualise time (e.g. years, months) as spatial sequences (Simner, Mayo, & Spiller, 2009). When cued with a year they were objectively able to generate more autobiographical memories to this cue (Simner et al., 2009). For this group it may be that dates are a special retrieval cue given the nature of their synaesthesia, and it is not clear whether the subjective quality of the retrieved memories differed in any way. As well as assessing objective performance, it would also be important to control more thoroughly for response bias. For instance, the AMQ has been criticised for not having reverse-coded items (Sutin & Robins, 2007). It is unlikely that this can explain our pattern of findings given that main effects of group were not found for Rehearsal or Impact, and that the pattern for the other constructs was not a simple additive effect of group.

In summary, we establish for the first time that the phenomenology of autobiographical memory of synaesthetes is richer. Moreover, this richness of autobiographical memories is

more pervasive across different life periods than in non-synaesthetes. This complements the previous literature showing that performance on many lab-based tests of episodic memory is enhanced.

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