CHARACTERISTICS/RELATED CONDITIONS

EFFECT OF A SYNESTHETE'S PHOTISMS ON NAME RECALL

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ABSTRACT

A multilingual, colored-letter synesthete professor (MLS), 9 nonsynesthete multilingual professors and 4 nonsynesthete art professors learned 30 names of individuals (first and last name pairs) in three trials. They recalled the names after each trial and six months later, as well as performed cued recall trials initially and after six months. As hypothesized, MLS recalled significantly more names than control groups on all free recall tests (except after the first trial) and on cued recall tests. In addition, MLS gave qualitatively different reasons for remembering names than any individual control participant. MLS gave mostly color reasons for remembering the names, whereas nonsynesthetes gave reasons based on familiarity or language or art knowledge. Results on standardized memory tests showed that MLS had average performance on non-language visual memory tests (the Benton Visual Retention Test-Revised – BURT-R – and the Rey-Osterrieth Complex Figure Test – CFT), but had superior memory performance on a verbal test consisting of lists of nouns (Rey Auditory-Verbal Learning Test – RAVLT). MLS's synesthesia seems to aid memory for visually or auditorily presented language stimuli (names and nouns), but not for non-language visual stimuli (simple and complex figures).

Key words: synesthesia, synesthete, colored hearing, mnemonical recall, cued recall

INTRODUCTION

When synesthetes experience one form of sensory input (e.g., letters, digits, tones), they simultaneously perceive an additional sensation (e.g., see color, see shapes, feel tingling). Synesthetes may experience different additional sensations from one another (e.g., colors *vs*. shapes for tones). Even those who experience the same type of sensation (color for digits) usually experience different specific responses (e.g., yellow *vs*. red for the digit 2). Thus synesthetic responses are very individualistic. Recent research focuses on synesthesia's influence on perception (e.g., Dixon et al., 2000; Mattingley et al., 2001; Mills et al., 1999, 2002, 2003; Wollen and Ruggiero, 1983). For example, Mills et al. (1999, 2002) using Stroop-type letter or digit stimuli, showed that synesthetes were faster at naming the color of the print when the color matched their synesthetic color for letters or digits than when it did not. This result suggests that synesthetes perceive their synesthetic colors (photisms) automatically for letters or digits.

Along with affecting perception, synesthesia may also increase memory performance. Subjective reports, such as the case of S (Luria, 1968), suggest that synesthetes possess heightened memory abilities in the domain(s) of their synesthesia, i.e., the types of stimuli that elicit photisms (sounds, digits, letters, tastes, etc.). S had multiple synesthetic domains, and in each domain his memory seemed to be increased. According to Luria (1968), "synesthetic components were important to his [S's] recall, for they created, as it were, a background for each recollection furnishing him with additional 'extra' information that would guarantee accurate recall".

Cytowic (2002) also discusses how synesthesia may affect memory. He suggests that, "synesthetes have a well-developed innate memory that is amplified by use of the parallel sense as a mnemonic device". Cytowic (2002) also describes synesthetes' reports on how they form a memory for a word or number based on their synesthetic responses as opposed to the actual content or meaning. One synesthete he studied stated, "I don't remember the name but I think it's blue".

As a result of these subjective reports as well as those of the synesthetes we have interviewed, we decided to more objectively study whether synesthesia increases memory by comparing a synesthete's memory with appropriate controls. In our previous research (Mills et al., 2002), we studied MLS, who is a multilingual colored-letter synesthete and a college professor of Russian. In repeated testing and in Stroop-type studies, we showed her to be a genuine synesthete. In interviews, MLS claimed that synesthesia helped her remember names and words and provided many examples of how she thought her photisms affected her recall.

When MLS is given words or names, she reports seeing colors fading in and out on a blank screen "inside her forehead". For example, if MLS was given a name like Carol Mills she said that she is usually not aware of experiencing colors related to the name but she would come away with

brown for the C and red for the M. She says "I'll remember that combination together. It's almost as if it's just there... If you need to use it, tap into it. It'll be there". Further, MLS stated that when she was desperately trying "to remember the name of something, an author, or something I want to discuss, and it was yellow, it was... yellow-green! And then if I can get a couple of letters [based on those colors] I might have a better chance of figuring out what the word is". These comments indicate that MLS believes that she relies on her synesthesia to remember names and words.

In addition to aiding her memory, MLS's synesthesia also influences her impressions and perception. She reported that the photisms she perceives for people's full names influence her impression of people. For example, MLS says, "I do sometimes remember people better if they have names that make a particular color impression on me". MLS also describes how she likes certain names based on their colors. For example, when deciding where to move, she liked the town name "Catonsville" because of the browns and greens in the name and bought a home there. Another example of how colors influence name perception, and even name selection, comes from MLS's naming of her son. She and her husband struggled to find a name that they both liked. Eventually, MLS realized part of her criteria for a suitable name involved names that "looked right" together based on their colors.

Because MLS believed that her name recall is increased by synesthesia, we decided to use first and last name pairs as test stimuli. We tested MLS along with controls – nine nonsynesthete, multilingual college professors and four nonsynesthete, art professors – for their ability to recall name pairs. The multilingual professors were included as controls because, like MLS, they all knew several languages, which may aid in encoding names. The art professors were included as controls because we expected them to engage in visual encoding, as MLS does, because of their artistic background. We hypothesized that MLS would be able to recall more names than either group of controls. MLS, unlike her nonsynesthetic colleagues, has a unique visual encoding aid to memory (color) available to her and, in general, previous research concludes that imageability enhances recall (e.g., Christian et al., 1978; Paivio, 1971). We also hypothesized that due to her synesthesia, her reasons for remembering names would be qualitatively different than her colleagues'. This second hypothesis stems from the idea that colored-letter synesthetes seem to use visual encoding based on their synesthesia as a way of remembering material. MLS's colleagues' reasons for recall would most likely be attributed to other types of associations, such as familiarity or prior knowledge.

Experiment 1

Method

Participants

Participants included MLS, a multilingual colored-letter synesthete and female professor of Russian (48 years old), as well as nine nonsynesthete, multilingual professors of modern languages (French, German and Spanish) and four visual art professors at a small liberal arts college. See Mills et al. (2002) for history and more detail about MLS's photisms and background. The nine nonsynesthete multilingual professors were two males and seven females, with an age range of 28-64 years and a mean age of 44.8 years. The four nonsynesthete visual art professors were all female with an age range of 41-56 and an average age of 49.5 years. For a second session, six months later, one language control and one art control were no longer available for participation. All participants received a fifteen-dollar bookstore certificate for their participation.

Materials

The following materials were used in our experiment: a list of 30 first/last name pairs plus six practice pairs, recall sheets, cued recall sheets, math problems and two background questionnaires.

First/last name pairs were randomly selected from a phone book using the following criteria: length of each first and last name was not to exceed 10 and 12 letters respectively; there was an equal number of male and female name pairs in the list and no first or last name was repeated. Each name of the first/last name pairs was to begin with different letters and each pair of these beginning letters had to be different color combinations based on MLS's color associations for the letters. This later selection criterion was used because for MLS, a name generally takes on the color of the first letter of the name, and we wanted to avoid interference effects that would be caused by names with the same color combinations. (refer to the Appendix for the list of names). Three separate PowerPoint presentations were developed, each having the 30 names in a different, random order.

The one-page recall sheet consisted of 30 blank lines, on which to write the names. Two one-page cued recall sheets were constructed: one had the first names in random order with a space to write the second name, and the other had the last names with a space for first names. A second version of each type of cued recall sheets was constructed using different, random orders. Simple math problems involving addition and subtraction were developed as a filler task between presentation and free recall.

Two questionnaires were developed to determine background information (e.g., language experience or art specialization, as well as the individual's age and sex). For example, one question on the language questionnaire was "What language did you acquire first?" and on the art questionnaire "For how many years have you taught each type of art?"

Procedure

Each participant was informed that the purpose of the experiment was to learn and recall names. They then read and signed a consent form. Participants were told that each name would be presented one at a time and that they should pay attention so they could later recall them.

First, in order to demonstrate the presentation and recall procedure, six practice names not on the experimental list were presented to the participants. The names were presented in 44 point, black Times New Roman font, on a white background in the center of a computer screen. The presentation began with a one second blank white screen followed by a name presented for five seconds, and then another blank white screen for one second and so on. Once the six names were presented, participants solved math problems for 20 seconds. They were then asked to recall the names they saw on the computer screen by writing each person's name on a separate line, in any order, on a sheet of paper. They were to write any part of the name that they could remember and guess if they could not remember the full name. Participants had 30 seconds to recall the six names.

The instructions for the first trial of the experiment were similar to the demonstration instructions with the exception that the participants were told the list consisted of 30 names and they would have three minutes to recall them. Participants were randomly assigned one of the three possible PowerPoint presentation orders. They then saw the names, did the math problems and recalled the names. After the three-minute recall session, participants were told they would be presented with the names again in a different order. After doing more math problems, participants had another three-minute recall sessions. Trial 3 followed the same procedure as Trials 1 and 2.

After completing Trial 3 free recall, participants were provided with the first names on a cued recall sheet and their task was to write in the corresponding last names. Again, they had three minutes for the task. Approximately half of the participants used one of the last name, cued recall sheets while half used the other.

After taking the cued recall test, the participants filled out the appropriate background questionnaire and were then interviewed as to why they thought they remembered each name they did. We gave them some example reasons such as knowing someone by that name, liking the way the name looks, liking the way the name sounds or the name's place in the list. Finally, participants were asked if they used any other means to recall the names that they thought we should know or anything else they wanted to tell us before they were finished.

After completing the interview, the purpose of the study was explained to participants and the phenomenon of synesthesia was described to the nonsynesthetic participants.

A preliminary look at the data revealed that the synesthete's recall was best overall compared to the two control groups, however on the first trials it was not the highest compared to individual controls. As a result, we decided to re-test the participants after a delay of approximately six months to determine if synesthesia provides an even greater long-term retention advantage.

Recall Session 2 was conducted in each participant's office. Participants were first reminded that several months ago we presented them with 30 names on the computer screen and they then recalled them. Now, we wanted them to recall any of those names they could still remember. They were not presented with the names again. After a free recall trial, they performed the cued test in which we gave them the first names of those they had studied. After the first cued recall test, participants were given another cued recall test in which we gave them the last names and asked for the corresponding first name. Next, the participants received the interview about why they remembered the names they did.

The morning after her second recall session, MLS sent us an unsolicited e-mail containing her free recall of all the names that she remembered that morning which had been on the list of names. She said that she tested herself and this is what she remembered. Since the number recalled increased dramatically overnight, we wanted to compare MLS's increase with nonsynesthetes'. For this purpose, we selected two of the nonsynesthete multilinguals who had the highest overall recall in Session 1 as controls. Because they had already completed their second session, we ran them for a third session, which means that they had an extra exposure to the task and the names during cued recall but their third sessions were later than MLS's second session. Immediately after this third recall session, the nonsynesthetes were instructed that on the following morning they were to free recall the names and e-mail their list to us. Hence, they had advantages over MLS of knowing they were to recall the names on the following day and of being exposed to the names an extra time.

Results

There were two types of data analysis: quantitative (number of names recalled) and qualitative (the reasons given for recall).

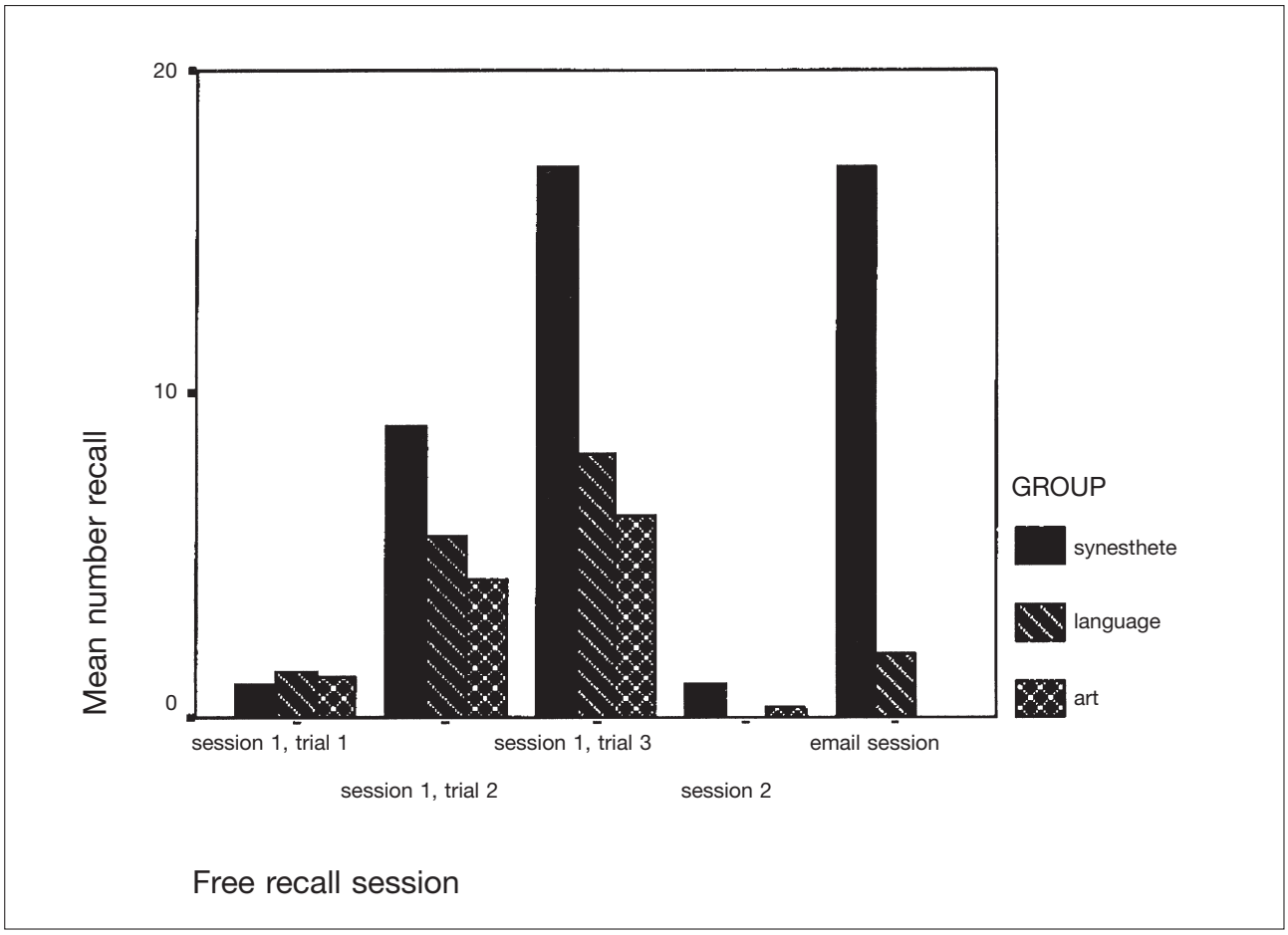

Fig. 1 – *Mean number free recalled (strictly scored) as a function of session, trial and group.*

Quantitative

The number recalled was scored using both a lenient and a strict scoring method. The lenient method allowed for phonetic variation of the name; however, the first letter for each part of the name had to be correct. Degree of correctness was scored depending on whether one or both names were correct. Under the strict scoring method, the participant had to recall the entire name (first and last) together for it to be correct. The name was considered correct with up to two misplaced, omitted or substituted letters; however, the initial letter of the first and last name had to be correct.

The pattern of results was similar for the lenient and strict scoring methods; therefore we will only present the results from the strict scoring. The mean number correct shown in Figure 1 supports our expectation that MLS would be better than either control group at free recalling the names. Compared to the two control groups, MLS had the highest level of recall on all the trials except Trial 1 of Session 1. A sign test was performed to determine whether MLS's free recall performance was better than the nonsynesthete language controls' for each trial and session. All the tests were significant except Session 1, Trial 1 (Session 1, Trial 1, $x = 1$, $n = 6$, $p > .05$; Session 1, Trial 2, $x = 7$, $n = 8$, $p < .05$ one-tailed; Session 1, Trial 3, $x = 9$, $n = 9$, $p < .01$ one-tailed; Session 2, $x = 8$, $n = 8$, $p < .01$ one-tailed; e-mail Session N was too small to conduct a sign test). The same pattern of results was obtained when MLS's free recall was compared to all controls' (both language and art combined). Except on Trial 1, Session 1, MLS recalled significantly more names than all control participants (Session 1, Trial 1, $x = 1$, $n = 7$, $p > .05$; Session 1, Trial 2, $x = 11$, $n = 12$, $p < .01$ one-tailed; Session 1, Trial 3, $x = 13$, $n = 13$, $p < .01$ one-tailed; Session 2, $x = 10$, $n = 10$, $p < .01$ one-tailed; e-mail Session N was too small).

We also expected MLS to do best on the cued recall. As seen in Figure 2, MLS consistently remembered more than either control group. Only in the first session, did one language control outperform MLS by two points. On all later sessions, MLS was the best on cued recall. The sign tests, conducted to determine whether MLS performed better on cued recall than the nonsynesthete language controls, confirmed our hypothesis (Session 1, $x = 8$, $n = 9$, $p < .01$ one-tailed; Session 2, first name cue, $x = 8$, $n = 8$, $p < .01$ one-tailed; Session 2, second name cue, $x = 8$, $n = 8$, $p < .01$ one-tailed). MLS's cued recall was also better than all controls' combined on all sessions (Session 1, $x = 12$, $n = 13$, $p < .01$ one-tailed; Session 2, first name cue, $x = 11$, $n = 11$, $p <$

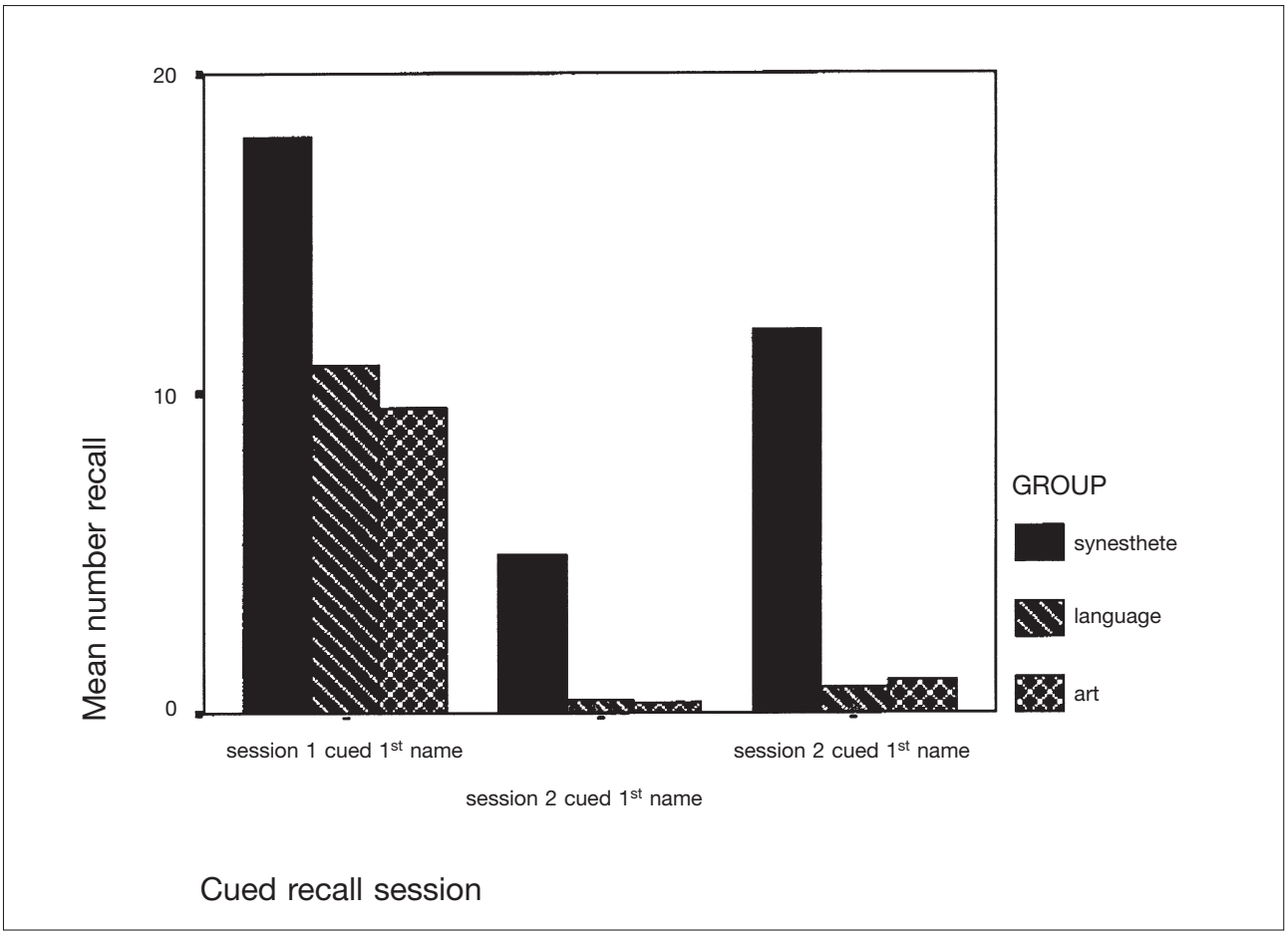

Fig. 2 – *Mean number cued recall (strictly scored) as a function of session, type of cue and group.*

.01 one-tailed; Session 2, second name cue, x = 11, n = 11, p < .01 one-tailed).

Qualitative

The two parts of the full name were considered independently when scoring the reasons given for recall. The reasons were scored in two ways: the first reason given for recall of the name pair and all the reasons given. Both methods of scoring yielded a similar pattern of results. However, since participants frequently gave a different reason for remembering the first and last names, the data will be presented both ways in Table I but analyses were done on first responses only because of the independence requirement for χ^2 statistical analyses.

In order to test the hypothesis that MLS would give reasons for remembering based on color and the controls would not, we separated the reasons into two categories: color association (e.g., the name Anderson is green) and non-color association (any reason not involving color). As hypothesized and can be seen in Table I, MLS gave mostly color-related responses; whereas, the nonsynesthetes gave other reasons such as they knew someone with the name, etc. In fact, about 80% of the reasons MLS gave for recalling the names were based on color (83% of the first reasons and 77% of all reasons combining both sessions) and none of the nonsynesthetes gave a color associated reason in either session. To determine whether MLS gave a significantly different pattern of reasons than the nonsynesthete controls, 2×2 χ^2's

TABLE I

Mean number of reasons given for recall in sessions 1 and 2 on correct responses[a]

	Type of response	
	Color	Non-color
	Synesthete	
Session 1	21 (61)	4 (11)
Session 2	13 (31)	3 (17)
Total	34 (92)	7 (28)
	Language professors[b]	
Session 1	0 (0)	22.88 (34.77)
Session 2	0 (0)	3.77 (5.39)
Total	0 (0)	26.65 (40.16)
	Art professors[c]	
Session 1	0 (0)	21.25 (33.5)
Session 2	0 (0)	3.00 (6.67)
Total	0 (0)	24.25 (40.17)

[a] This table includes first reasons given for recall (all reasons are included in the parentheses). The reasons for recall in this table are for name pairs correctly recalled (correct pairing of first and last name), as well as for names in which only one part was recalled or both parts were recalled but not together.
[b] Language professors: n = 9 for Session 1 and n = 8 for Session 2.
[c] Art professors: n = 4 for Session 1 and n = 3 for Session 2.

were performed comparing MLS with each control for the first reasons given. The results showed that MLS gave a significantly different response pattern than all individual controls [χ^2 (1) = 21 to 40, p's < .001].

Experiment 2

The results of Experiment 1 supported our hypotheses that MLS has a superior memory for names. However, it is possible that she has a superior memory for all information and not just the verbal information which elicits her synesthetic photisms. To test this, we administered three standardized neuropsychological memory tests to MLS: Benton Visual Retention Test-Revised (BVRT-R) (Benton, 1974), Rey-Osterrieth Complex Figure Test (CFT) (Spreen and Strauss, 1998) and the Rey Auditory-Verbal Learning Test (RAVLT) (Spreen and Strauss, 1998). The BVRT-R and CFT are both non-language visual tests which consist of figure drawings and should not elicit MLS's synesthesia. As a result, she should not do as well on these tests relative to norms as she does on a test that is verbal and would elicit her synesthesia, i.e., RAVLT. The RAVLT was also included in this study to determine whether MLS only recalls visually presented proper names like those used in Experiment 1 at a superior level or whether this would also occur for other verbal information. The RAVLT consists of auditorily presented common nouns and should result in superior performance as well, if synesthesia is elicited by the nouns.

Method

MLS served as the participant and at the time of testing was fifty years old. The tests were administered in a quiet room in the order BVRT-R, RAVLT, CFT. Standard instructions were read and standard procedures were followed as given in Benton (1974) and in Spreen and Strauss (1998).

An additional task was added at the end of the testing. MLS was asked to recall the words from the RAVLT and the figure from the CFT on the morning following the testing and send it to the experimenters. This was added because based on the e-mail recall trial in Experiment 1, she may remember information better the next day than immediately after presentation.

MLS's test results were scored using the standard methods described by Benton (1974) and by Spreen and Strauss (1998).

Results

The results of the three tests are shown in Tables II, III and IV relative to the comparisons provided by Benton (1974) and by Spreen and Strauss (1998).

The results of the two visual tasks, the BVRT-R and the CFT, show that MLS performed in the expected range. On the BVRT, she scored a little better than expected but within one standard deviation of the mean in the norm group. For the CFT, she obtained an average score for someone her age, in one case slightly lower and in another slightly higher but within one standard deviation. On the other hand, for the RAVLT, she performed consistently better than the norm group. For each measure, she scored 1/2-2 standard deviations above the norm. On the RAVLT, MLS performed the day after testing she obtained a perfect score of 15 after missing only one word on the later trials on the previous day.

A couple of days after these three tests were completed, we asked MLS if she was aware of synesthesia being elicited and being used during these tests and if so how. She reported that she used synesthesia for the words but not for the visual figures. She describes this in an e-mail which is included below. To understand this e-mail, the 15-word list for the RAVLT was: drum, curtain, bell, coffee, school, parent, moon, garden, hat, farmer, nose, turkey, color, house and river. In the RAVLT this list is given five times, followed by a different list of 15 words, followed by recall of the first list again, and then a recognition test. MLS wrote:

"The first time through the list the top two words on the list (drum and curtain) were too indistinct to recall immediately. Their beginning letters didn't stand out. The first word that really stood out in visual memory was 'bell' – it was black and blue, shiny and powerful.

The second time through the list was easier because I remembered (made a point of 'seeing') that the first word on the list (drum) began with that indistinct grey/blue. Next my left inner eye seemed to pull toward the 'curtain' behind you. Remember you were sitting opposite me at the table in front of the curtain. 'Bell' again popped out visually as it had the first time, but when I tried to recall the 'brown' word that came after 'bell', my right inner eye stretched toward the kitchen behind me where 'coffee' would be found. The next word in the list (school) popped up brightly on my inner screen. Yellow words seem to be easiest to

TABLE II
MLS's scores on Benton Visual Retention Test-Revised compared to means

	Number correct	Error score
MLS	9	1
Expected score for 40-54-year-olds with IQ 110 or above[a]	8	2
Mean for 18+ years of education for 50-59-year-olds[b]	7.55 (1.53)	3.64 (2.76)

SDs are in parentheses for the norm scores.
[a] From Benton (1974).
[b] From Spreen and Strauss (1998).

TABLE III
MLS's scores on Rey-Osterrieth Complex Figure Test compared to means

	Copy	30-minute recall	Next day recall
MLS	28.50	17.50	16.00
50-59-year-olds[a]	31.19 (3.68)	14.88 (6.95)	—

SDs are in parentheses for the norm scores.
[a] From Spreen and Strauss (1998).

TABLE IV
MLS's scores on Rey Auditory-Verbal Learning Test compared to means

	Trial 1 List A	Trial 2 List A	Trial 3 List A	Trial 4 List A	Trial 5 List A	Total	Distractor List B
MLS	10	12	14	14	14	64	9
50-59 year-olds[a]	6.3 (2.0)	8.7 (2.1)	10.5 (2.2)	11.2 (2.2)	11.8 (2.0)	48.5 (8.4)	5.2 (1.8)

	Trial 6 List A	Trial 7 List A	Recognition List A	Recognition List B	Trial 8 List A	Trial 8 List B
MLS	14	14	14	9	15	7
50-59 year-olds[a]	10 (3.4)	10 (3.4)	12.1 (2.7)	6.0 (3.3)	—	—

SDs are in parentheses for the norm scores.
[a] From Spreen and Strauss (1998).

remember. Once I had 'school' – 'parent' came by semantic association. I remembered parent as something meaningfully associated with a school. 'Moon' popped up easily. It's a big, red word – beautiful, actually. 'Moon' brought 'garden' through both content association and aesthetics. I pictured a moon over a garden – all bathed in reds and oranges. 'Hat' was hard to remember – very grey and indistinct – but when I placed it on the 'farmer's' head it was easier to remember and to place in the list after 'garden'. The reds and oranges at the heart of the word 'farmer' supported the connection with moon/garden and made 'farmer' easier to remember.

I don't want to take the time at this point to go through the rest of the list, but I did want to mention the indistinct colors at the end of the list – the grey wispiness of 'house' and the light brown dullness of the word 'color' caused me to get stuck and forget the end of the list. I missed the word 'river' until you gave me the list to look at (on recognition test). Once I saw that red word I knew I wouldn't forget again. I consciously imprinted it.

In the second list color impression was the primary support for my memory. All the words I remember from the list, with the exception of the first word (desk), are yellow, red or white coupled with bright colors (ranger, mountain, stove, shoe, lamb). Those colors seem to imprint faster.

The figures (of the BVRT-R and CFT) are not in color at all in my memory. I see black lines. In fact they are the opposite of the word memories. They are thin, flat, two-dimensional, while the words are fleshy and three-dimensional. The words seem to take on color and texture – meat – as I contemplate them, while the figures seem to lose detail – to simplify – as I contemplate and try to memorize them.

In short, I remember the figures as skeletons and the words as flesh. It sounds like I'm being cute and poetic, but this really is the best way for me to give an accurate description of what I see".

MLS's scores on the standardized tests show that she is better on verbal memory tasks than visual ones and that her superior recall for verbal materials is not just limited to visually presented proper names, but also extends to auditorily presented nouns. Her self-report suggests that she uses colors, in some cases augmented with other associations, to aid her recall.

Discussion

Our results support both of our hypotheses: the synesthete (MLS) recalled significantly more names than either language or art controls; and the synesthete gave qualitatively different reasons for recall than controls. MLS's performance was not the best initially when compared to the control participants, and in fact, her free recall was one of the worst in Session 1, Trial 1. However, it improved dramatically over sessions and trials. This pattern suggests that she does not depend on superior memory per se but develops distinctive synesthetic encodings based on color. The more she is exposed to a name, the more she seems to encode the name based on her photisms, which helps her recall the name. Further, the results for the standardized memory tests showed that she does not have a superior memory for figures but does for verbal materials. These results show that memory

performance of synesthetes can be enhanced by synesthesia for stimuli that elicit photisms.

The synesthetic encodings seem to be particularly effective in aiding long-term retention compared to the controls'. In Session 2, approximately six months later, MLS was better at both free recall and cued recall than any of the individual controls. Consistent with her self-reports, she seemed to be able to remember the color combinations of the first and last names which particularly aided cued recall. Giving MLS one name (and therefore color) aided her retrieval of the other color and then name. This effect was particularly evident for the last name cues in Session 2 (perhaps because professors concentrate on remembering the first names of students). Also, in the e-mail session, it appears that the re-exposure of the single names in Session 2 cued recall elicited the retrieval of the photisms and then the names.

A recent study by Smilek et al. (2002) also provides evidence that synesthesia enhances recall. They had a colored-digit synesthete and seven control nonsynesthetes recall three matrices of 50 digits: a black one, a colored one congruent in color with the synesthete's photisms and another colored one which was incongruent with the photisms. Participants studied each matrix a total of four times for three minutes each. Then, they had a three-minute recall period after each presentation during which they reported as many of the digits as they could remember by filling in the squares of a matrix. On the first day, participants were presented with the black matrix and the congruent matrix. Two days later, participants were to recall as many digits as they could from the black digit matrix and were then presented with and were tested on the congruently colored digits. Smilek et al.'s results for immediate recall indicated interference by the incongruently colored digits compared to black digits or congruently colored ones. After a 48-hour retention interval, unlike the nonsynesthetes', the synesthete's recall of the black digits was not reduced. These results suggest that the synesthete's memory ability was enhanced by synesthesia, especially over a two-day interval. Hence, the results are consistent with those from the present study in that both suggest that synesthesia aids memory, particularly after a time delay.

MLS's reasons for remembering the names are qualitatively different from the controls' since her reasons were primarily based on the color photism combinations. The other language professors reported associations based on the familiarity and the ethnicity of the names, while the art professors reported associations based on familiarity and art knowledge. For MLS her synesthetic photisms seemed to form the basis for her superior recall of names. Synesthesia provided an additional type of encoding and one which she seemed to primarily rely upon, based on the fact that 80% of the reasons she gave for recall were based on color (83% of the first reasons and 77% of all reasons). This suggests that her synesthesia acts as a primary encoding device for recall.

Some of the reasons she gave for recalling the names illustrate how synesthesia influenced her memory. Prior to this study, MLS mentioned that when learning words or names, the first letter or two of a word creates the color impression. Most of the names in this study did that based on her reasons for remembering the names. The first letter of the first and last name elicited colors, and she used those to remember the name pair. However, one name, Charles Garrett, in the present study failed to make an impressionable color combination and resulted in her inability to recall the name. Also, when the first letters did not make a distinctive color impression, she reported that she looked further into the name (e.g., in the present study for the target Donna Hooley by using the O's in the two names to encode them). Furthermore, she reported that sometimes she can remember the colors of names but cannot recall the actual names. While synesthesia seemed beneficial for name recall, it also ironically served as a source of interference for a few names in the present study despite our attempt to avoid such effects through our selection criteria for the names. An unpleasant or mismatched color combination at the beginning of a pair of names failed to be encoded together or were encoded as mismatched and MLS had more trouble recalling them. For example, for the target name Gloria Zuckerman, MLS reported "The names don't go together. They are mismatched". MLS experienced another type of interference when she substituted a name that was similar to the target stimuli and made a "better" color combination, e.g., when she was trying to recall the name Jason Younger; instead, she recalled the name as Jerry Younger (later letters on the names must have influenced the color impressions). Hence, MLS's synesthesia seems to play an integral role in how she recalls names: in most cases it enhanced her ability, but in a few instances it interfered with her recall. Further exploration of synesthesia's effects on memory could systematically explore facilitation and interference.

The fact that MLS's recall increased so dramatically in the e-mail recall is reminiscent of her performance in our earlier research with her (Mills et al., 2002). In that research, which employed the Stroop paradigm, MLS acquired new temporary letter-color pairings by the next day based on the mismatched (according to her synesthesia) letter-color pairings that we used in the experiment. These temporary pairings lasted at least a week but after three months they were mostly gone. However, even after the pairs had decayed with time the new-letter color pairs were revived with re-exposure.

Similarly, in the present experiment, in Session 2 after six months had passed since the initial exposure, she did not free recall very many names.

But after re-exposure to the individual first and last names during cued recall (but never the pairs) and an overnight consolidation period, her recall was equivalent to what it had been at the end of the three trials in Session 1. In contrast, the recall of the two controls who completed the e-mail session was dramatically reduced.

Based on all of our research with MLS, it appears that initially she forms strong synesthetic color associations which enable her to remember information very well. Over time, these associations weaken without re-exposure to the information. However, with re-exposure to just some of the information and an overnight consolidation period, she gets the photisms back which enables her to reconstruct the remembered information (i.e., name pairs, letter-color pairs or nouns). An overnight consolidation period seems to be necessary to this memory process for MLS and is consistent with recent research suggesting that memories consolidate during sleep (e.g., Maquet, 2001; Stickgold et al., 2001).

It might be argued that the results are due to MLS being highly motivated to remember the names, given that she spontaneously e-mailed us after the second session with the names that she remembered. However, we do not believe that motivation alone can account for the pattern of results. First, note that this pattern of e-mailing us after an experimental session was set up in the previous research (Mills et al., 2002). In that context it was not unusual to e-mail us with what she remembered even though we had not requested it. Secondly, high motivation cannot account for her qualitatively different pattern of reasons for remembering the names. She has a unique synesthetic ability which she utilizes for memory tasks. The two nonsynesthetes who participated in the e-mail session were also highly motivated as evident from their high scores in the initial sessions and their expressed concern for how they were performing. Even though the two controls had an additional exposure to the names in a third session and knew they were to remember the names until the next day, their performance did not match MLS's. Thirdly, if only motivation was what led to MLS's superior memory performance, then on the standardized tests she should have performed equally well on the visual and verbal tests, but her best performance was on the verbal test.

In summary, MLS has a synesthetic ability to perceive both visually and auditorily presented language stimuli which aids her in recalling them and recalling them based on her color encodings. Motivational factors cannot account for the obtained pattern of responses, but seeing her colors can. The present results, along with those of Smilek et al. (2002), suggest that synesthesia can enhance memory for stimuli in the synesthetic domain.

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References

BENTON AL. *Revised Visual Retention Test* (4th ed). New York: The Psychological Corporation, 1974.

CHRISTIAN J, BICKLEY W, TARKA M and CLAYTON K. Measures of free recall of 900 English nouns: Correlations with imagery, concreteness, meaningfulness and frequency. *Memory and Cognition, 6:* 379-390, 1978.

CYTOWIC RE. *Synesthesia: A Union of the Senses* (2nd ed). Cambridge, MA: MIT Press, 2002.

DIXON MJ, SMILEK D, CUDAHY C and MERIKLE PM. Five plus two equals yellow: Mental arithmetic in people with synesthesia is not coloured by visual experience. *Nature, 406:* 365, 2000.

LURIA AR. *The Mind of a Mnemonist: A Little Book about a Vast Memory*. Cambridge: Harvard University Press, 1968.

MAQUET P. The role of sleep in learning and memory. *Science, 294:* 1048-1052, 2001.

MATTINGLEY JB, RICH AN, YELLAND G and BRADSHAW JL. Unconscious priming eliminates automatic binding of color and alphanumeric form of synaesthesia. *Nature, 410:* 580-582, 2001.

MILLS CB, BOTELER ED and OLIVER GK. Digit synesthesia: A case study using a Stroop-type test. *Cognitive Neuropsychology, 16:* 181-191, 1999.

MILLS CB, BOTELER EH and OLIVER GK. Seeing things in my head: A synesthete's image for music and notes. *Perception, 32:* 1359-1376, 2003.

MILLS CB, VIGUERS ML, EDELSON SK, THOMAS AT, SIMON-DACK SL and INNIS JA. The color of two alphabets for a multilingual synesthete. *Perception, 31:* 1371-1394, 2002.

PAIVIO A. *Imagery and Verbal Processing.* New York: Holt, Rinehart and Winston, 1971.

SMILEK D, DIXON MJ, CUDAHY C and MERIKEL PM. Synesthesic color experiences influence memory. *Psychological Science, 13:* 548-552, 2002.

SPREEN O and STRAUSS E. *A Compendium of Neuropsychological Tests: Administration, Norms and Commentary* (2nd ed). New York: Oxford University Press, 1998.

STICKGOLD R, HOBSON JA, FOSSE R and FOSSE M. Sleep, learning and dreams: Off-line memory reprocessing. *Science, 294:* 1052-1057, 2001.

WOLLEN KA and RUGGIERO FT. Colored-letter synesthesia. *Journal of Mental Imagery, 1:* 83-86, 1983.

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Appendix

List of names used in the study

Kirk Abbott	Tammy Kohberg
Daisy Anderson	Earl Lawson
Jerry Beasley	Maria Lollie
Valerie Brantly	Birtie McDorsey
Brian Cathcart	Gary Monroe
Nancy Costanzo	Kevin Nesbit
Kenneth Dougal	Josie Noland
Shawn Isaacs	Mervin Pollon
Gloria Zuckerman	Cindy Polston
Ralph Tabler	Dennis Rodgers
Charles Garrett	Louise Sheer
Tracy Griffin	Nicole Stokes
Walter Herschel	Craig Wortley
Donna Hooley	Sidney Wright
Oliver Zachary	Jason Younger