Title
The role of visual imagery in autobiographical memory

Journal
Memory & Cognition, 42(6)

ISSN
0090-502X

Authors
Greenberg, Daniel L
Knowlton, Barbara J

Publication Date
2014-08-01

DOI
10.3758/s13421-014-0402-5

Peer reviewed

Mem Cogn (2014) 42:922–934
DOI 10.3758/s13421-014-0402-5

The role of visual imagery in autobiographical memory

Daniel L. Greenberg · Barbara J. Knowlton

Published online: 20 February 2014

Abstract Visual imagery plays a fundamental role in autobiographical memory, but several aspects of this role remain unclear. We conducted three experiments to explore this relationship. In the first experiment, we examined the relation between the phenomenological properties of autobiographical memory and several measures of visual-imagery ability. We found no significant positive relation between imagery ability and autobiographical memory, except on a measure of cognitive style. In a second experiment, we examined the autobiographical memories of people with different cognitive styles—namely, visualizers and verbalizers. We found that, for both kinds of participant, visual imagery was correlated with the feeling that they were reliving their memories, but auditory imagery played a greater role in verbalizers. In a third experiment, we examined the memories of individuals who had a congenital absence of visual imagery. We found that they had a deficit of auditory imagery, as well; moreover, they were much less likely than controls to feel as though they were reliving their memories. The results support the idea that visual imagery plays a vital and irreplaceable role in autobiographical recall.

Keywords Autobiographical memory · Imagery

Autobiographical memories are memories for the events of everyday life. For most people, these memories tend to come with a *sense of reliving*—a feeling that one is reexperiencing the original event. William James argued that this feeling is a vital component of memory:

> Memory requires more than mere dating of a fact in the past. It must be dated in *my* past . . . I must think that I directly experienced its occurrence. It must have that "warmth and intimacy" . . . [that] characteriz[es] all experiences "appropriated" by the thinker as his own. (James, 1890/1950, p. 650)

Modern authors have made a similar distinction. Tulving, for instance, suggested that episodic memory (of which we consider autobiographical memory a part) involves *autonoetic consciousness*, or consciousness of a previous conscious experience (e.g., Tulving, 1985). For these reasons, other work (Baddeley, 1992; Brewer, 1996), including our own (Greenberg & Rubin, 2003; Rubin, Schrauf, & Greenberg, 2003), has held that this sense of reliving is a defining feature of autobiographical memory—that it distinguishes autobiographical memory from other forms of memory, such as semantic or implicit retrieval. This notion is no mere philosophical contrivance: People with retrograde autobiographical amnesia can learn about what happened during the amnesic period, but they may nevertheless maintain that they do not really *remember* it. The relearned experience feels as though it could very well have happened to someone else, precisely because it lacks the "warmth and intimacy" that marks it as their own.

Similarly, when we retrieve an autobiographical memory, we tend to believe that the original event actually happened more or less as we remember it. As the vast literature on false memory has shown, this belief may or may not be accurate. Moreover, recollection and belief are not identical, nor even strongly correlated (Mazzoni & Kirsch, 2002; Rubin et al., 2003; Scoboria, Mazzoni, Kirsch, & Relyea, 2004). We can relive a memory without fully believing in its accuracy (as when we "could have sworn" that an event happened in one

D. L. Greenberg (✉)
Department of Psychology, College of Charleston, 66 George Street, Charleston, SC 29424, USA
e-mail: greenbergdl@cofc.edu

B. J. Knowlton
Department of Psychology, University of California, Los Angeles, CA, USA

way, only to find out that it did not). In fact, research on "nonbelieved memories" has shown that experimental procedures can lead people to have memories that they vividly relive yet know to be false (Otgaar, Scoboria, & Smeets, 2013). Conversely, we can believe in a memory that does not come with much in the way of reliving (as in a dimly remembered but well-documented event from early childhood).

Reliving and belief are two of the most fundamental metacognitive components of autobiographical memory, but they are not the only components involved. Most theoretical accounts propose that autobiographical memory is a complex cognitive process that draws on many other processes, both metacognitive and not. Conway and colleagues' model (e.g., Conway & Pleydell-Pearce, 2000) posits that autobiographical knowledge can be divided into at least three levels of specificity: *lifetime periods*, *general events*, and *event-specific knowledge*, with the last of these levels consisting largely of sensory–perceptual information. Rubin and colleagues have outlined a *multiple-systems model* of autobiographical memory (Rubin, 2006) in which autobiographical memories consist of a number of components that are behaviorally and neuropsychologically distinct, including sensory imagery, emotion, and narrative coherence. Although these models posit different organizational structures for autobiographical knowledge, they both maintain that autobiographical memories rely heavily on specific sensory–perceptual data.

Sensory–perceptual data can come in any one of several modalities, but visual imagery appears to be the most important (Brewer, 1988, 1996; Brewer & Pani, 1996). Our most powerful autobiographical memories—those that come with a strong sense of reliving—almost always come with vivid visual images (Rubin et al., 2003). Visual images are a key part of flashbulb memories, which is presumably why Brown and Kulik (1977) did not name them "audiotape memories." Furthermore, participants are more likely to believe memories that are accompanied by vivid visual images (Rubin et al., 2003; but see Clark, Nash, Fincham, & Mazzoni, 2012, for an interesting counterexample). As we noted above, this belief is not always justified, since visual images can be used to "implant" memories for events that never occurred (e.g., Hyman & Pentland, 1996; Loftus & Pickrell, 1995). Thus, visual imagery is closely linked to reliving and belief, two important metacognitive properties of autobiographical memories.

Neuroscientific evidence has provided further evidence for the importance of visual imagery to autobiographical recall. Neuropsychological studies have revealed that people with an acquired imagery deficit often have profound autobiographical amnesia (Greenberg, Eacott, Brechin, & Rubin, 2005; Greenberg & Rubin, 2003; O'Connor, Butters, Miliotis, Eslinger, & Cermak, 1992; Ogden, 1993). Neuroimaging studies have demonstrated that autobiographical retrieval is associated with increased activation in posterior cortical regions that play a role in visual imagery (for reviews, see Cabeza & St. Jacques, 2007; Spreng, Mar, & Kim, 2009; Svoboda, McKinnon, & Levine, 2006). Taken together, the behavioral and neurological evidence suggests that visual imagery and autobiographical memory are closely intertwined.

Several important aspects of this relationship remain unclear, however. First, we know that individuals vary in their ability to generate vivid visual images (Galton, 1880a, b; see Richardson, 1994, for a review). Does visual imagery play different roles in strong and weak imagers? For instance, do strong imagers have a more powerful sense of reliving than weak imagers do? Are strong imagers more likely to believe their memories? To the best of our knowledge, only one previous study has addressed this question (D'Argembeau & Van der Linden, 2006). In this study, participants were given the Vividness of Visual Imagery Questionnaire (Marks, 1973) and were also asked to generate seven autobiographical memories and rate their phenomenological properties on a series of scales. The researchers found that VVIQ scores were significant predictors of the level of visual detail in the memory, the level of other sensory detail, and the amount of temporal information; however, these scores did not predict the intensity of the memories, their personal importance, or any other measured property. In our first experiment, we therefore attempted to clarify the relationship between visual imagery and autobiographical memory by conducting a more comprehensive study that would examine more memories and more measures of visual imagery.

Second, individuals do not differ just in their *ability* to use visual images, but also in their *tendency* to do so. That is, they differ in their cognitive style. According to one view, some people are visualizers, tending to use visual imagery to handle a range of cognitive tasks; others are verbalizers, who tend to use verbal strategies instead (Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov, Kosslyn, & Shephard, 2005; Mayer & Massa, 2003). Could visual imagery play different roles in visualizers and verbalizers? To the best of our knowledge, no studies have addressed this question, and we therefore examined it in our second experiment.

In our third experiment, we asked a stronger question: How does autobiographical memory work in people who have no visual-imagery ability whatsoever? Can another sensory modality or cognitive process take its place, or are we truly "visual creatures" after all? Several lines of research have shed light on this question, but they have not yet yielded a definitive answer. As we noted earlier, people who lose visual imagery because of a neurological injury tend to have severe retrograde amnesia; their anterograde memory tends to be better, although the data are quite meager, and we do not know why these memories are not as severely affected (Greenberg et al., 2005; Greenberg & Rubin, 2003; O'Connor et al., 1992; Ogden, 1993). Although these cases suggest that visual imagery plays a vital role in autobiographical memory, they only tell part of the story. These individuals originally encoded memories with visual imagery (or so we presume), so it may be no surprise that they have autobiographical amnesia, given that they have lost key parts of the memory that they had once possessed.

Other insights have come from studies of people with optical blindness. Eardley and Pring (2006) used the Galton–Crovitz cue-word method (Crovitz & Schiffman, 1974) to elicit autobiographical memories from congenitally blind and sighted participants. They found that sighted participants retrieved more memories as well as a greater number of specific memories, suggesting that visual imagery, or at least vision, is important for detailed autobiographical recall. Similarly, Ogden and Barker (2001) examined autobiographical memory in congenitally blind, late-blind, and sighted participants. They found that late-blind participants still had visual imagery in their memories, whereas early-blind participants did not; they also found that the memories of blind individuals were somewhat less detailed than those of sighted controls. Thus, some previous work has examined people who had visual imagery and then lost it, and other work has examined people who have neither vision nor imagery. Here we took a different approach, by examining autobiographical memory in people whose deficit is specific to visual imagery.

We addressed these issues with the help of the Autobiographical Memory Questionnaire (AMQ; Rubin et al., 2003). This questionnaire uses the Galton–Crovitz technique to elicit autobiographical memories. Participants are given a cue word (such as TREE) and asked to come up with an associated autobiographical memory. They are then asked to rate the memory on a series of Likert-type scales. Each rating scale is anchored by its logical extremes: for the visual-imagery question, the minimum is defined as *not at all*, and the maximum is defined as *as clearly as if it were happening right now*. Table 1 provides a summary of the AMQ measures that we used in the experiments reported here; the full questions are listed in the Appendix. Each study used a slightly different set of rating scales. Table 1 also identifies which questions were used throughout each experiment, and for comparison purposes, we will focus on the questions that were consistent across all versions.

Each of these questions is based on the multiple-systems model described above, and thus each examines a different aspect of autobiographical memory (see Rubin et al., 2003, for a fuller explanation of the rationale behind the questions). This approach differs from other methods that ask participants to write out their memories in detail (e.g., Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). By focusing on ratings, we were able to collect more memories and more ratings than would otherwise be feasible, and participants could choose memories that they would not otherwise wish to disclose to experimenters. Furthermore, since we were interested in the phenomenological properties of autobiographical memory, and since these properties are only accessible to the person retrieving the memory, the AMQ is the optimal choice to answer the questions that we have raised here. By combining the AMQ with well-established measures of visual imagery, we endeavored to explore and clarify the role that visual imagery plays in fundamental properties of autobiographical memory.

Experiment 1

Method

Participants A group of 101 undergraduates participated in this experiment for course credit. Three were excluded

Table 1 Autobiographical memory variables used in Experiments 1–3

Variable Name	Brief Description	Used in Experiments
Visual imagery	I can see it in my mind	1, 2, 3
Reliving	I am reliving the original event	1, 2, 3
Belief	I believe the event really occurred as I remember it	1, 2, 3
Remember/know	I remember it rather than just know it happened	1, 2, 3
Setting	I can recall the setting	1, 2, 3
Auditory imagery	I can hear it in my mind	1, 2, 3
Talking	I or other people are talking	1
In words	The memory comes to me in words	1, 2, 3
Narrative coherence	The memory comes to me as a coherent story	1, 2, 3
Emotional arousal	I feel now the emotions I felt then	1, 2, 3
Positive	The emotions I feel are positive	2
Negative	The emotions I feel are negative	2
Rehearsal	I have thought or talked about this event	1, 2, 3
Merged/extended	The event was a merging of similar events or an extended event that lasted longer than a day.	1
Age of memory	The age of the memory in days	1, 2, 3

because they failed to provide dates for three or more memories. The mean age of the remaining participants was 19.3 years (*SD* = 1.2), and 64 were female and 34 were male. The data from 65 of these participants were collected at Duke University and had previously been reported in Rubin and colleagues' (2003) Experiment 1; the results here come from analyses of imagery data that were not reported in that article. The data from the remaining 33 participants were subsequently collected at the College of Charleston and have not previously been reported.

Materials and procedure Each participant was presented with the AMQ, which consisted of a cover page with instructions, a double-sided sample page, a dividing page, and 15 additional double-sided pages containing 15 cue words from Rubin et al. (2003). The words were as follows: TREE, CANDY, CITY, DOCTOR, DRESS, HEALTH, FRIEND, HORSE, MONEY, RIVER, ANGER, OCEAN, FIRE, LOVE, MOTHER, and PARTY. We used the MRC Psycholinguistic Database (Wilson, 1988; accessed from http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm) to calculate the concreteness, imageability, and frequency of these words, and found that they had a mean concreteness rating of 525.8 (*SD* = 105.3), a mean imageability rating of 590.7 (*SD* = 55.3), and a mean Kučera–Francis frequency of 147.1 (*SD* = 100.7). The pages also contained a series of questions about each memory (see Table 1 for the questions used in this experiment). Note that the original 65 participants were asked three questions that were not asked the College of Charleston participants; here we report the questions that were asked every participant. Participants were also given the Beck Depression Inventory (Beck, Steer, & Brown, 1996); these results were previously reported by Rubin et al. and will not be discussed further here.

The participants were also given a series of visual-imagery questionnaires. The VVIQ (Marks, 1973) asks participants to visualize several scenes (both with eyes open and with eyes closed) and rate the vividness of the generated image on a series of 5-point scales. The Visual Elaboration Scale (VES; Slee, 1980) takes a different approach: It asks people to think about a particular situation (such as a house), and then asks about the extent to which visual images appeared in their thoughts. It thus helps distinguish between visualizers and verbalizers (Richardson, 1994). The Mental Rotation Test (MRT; Peters et al., 1995; Vandenberg & Kuse, 1978) is thought to rely more heavily on spatial imagery; it asks participants to compare two objects—three-dimensional arrangements of blocks—and determine whether they are identical. Finally, the Controllability of Visual Imagery Questionnaire (CVIQ; Gordon, 1949) asks participants to generate and manipulate visual images. In this way, each questionnaire tapped a different aspect of visual imagery, and might therefore describe a different role in the belief and recollection of autobiographical memories.

Participants were tested in groups. They were read the printed instructions on the AMQ and were asked to think of a memory to the word TREE and then answer all of the questions about it. Each of the questions was discussed briefly, and the experimenter answered any questions that arose. The participants were then asked to recall a memory for each of the remaining 15 cue words and rate them on the scales. Specifically, they were asked to remember as much of the memory as possible before beginning to rate it. The memory portion of the task was self-paced, and participants generally took between 1 and 1.5 h to complete it. They next went on to complete the Beck inventory and the various imagery questionnaires.

Results

Table 2 presents the means and standard deviations for the autobiographical memory and imagery variables.

We calculated the zero-order correlations between reliving, belief, the AMQ variables, and the visual-imagery variables. Table 3 presents the results. The first four columns of data report the correlations between the imagery questionnaires and the AMQ variables. The fifth column reports the correlations between the AMQ's measure of visual imagery and the other variables assessed by the questionnaire. Note that these correlations were calculated between subjects: Each participant contributed a single value for each variable (which was obtained by averaging that participant's memories together). These correlations show whether a participant who tended to give high ratings on one scale also gave high ratings on another.

Table 2 Means and standard deviations of variables in Experiment 1

Variable	Mean	*SD*
VVIQ	2.47	0.86
VES	10.34	2.24
MRT	16.92	5.76
CVIQ	10.00	2.79
Visual imagery	5.52	0.82
Reliving	4.83	1.10
Belief	6.03	0.83
Remember/know	5.97	0.78
Setting	5.86	0.73
Auditory imagery	4.27	1.26
Talking	4.42	1.14
In words	3.04	1.49
Narrative coherence	4.76	1.17
Emotional arousal	4.62	1.01
Rehearsal	3.60	1.17
Merged/extended	1.37	0.27
Age of memory (days)	1,751.33	780.95

Table 3 Between-subjects correlations between key Autobiographical Memory Questionnaire (AMQ) variables and imagery questionnaires

	VVIQ	VES	MRT	CVIQ	Visual Imagery	Reliving
VVIQ	–					
VES	.12	–				
MRT	–.08	–.02	–			
CVIQ	–.14	**.20**	**.38**	–		
Visual imagery	.04	**.30**	**–.29**	–.03	–	
Reliving	.12	**.20**	**–.38**	–.06	**.72**	–
Belief	–.14	.14	**–.26**	–.13	**.51**	**.41**

VVIQ, Vividness of Visual Imagery Questionnaire; VES, Visual Elaboration Scale; MRT, Mental Rotation Test; CVIQ, Controllability of Visual Imagery Questionnaire. Correlations in boldface are significant at $p < .05$.

As in previous studies, we found strong between-subjects correlations between visual imagery and the other scales on the AMQ, including the scales that measured reliving and belief. Thus, people whose memories had strong visual imagery also tended to relive and believe their memories. The visual imagery questionnaires, however, generally did not correlate positively with reliving, belief, or the other AMQ variables. Nor did they significantly correlate with the age of the memory (all $|r|$s < .17, all ps > .05). The only exception was the correlation between the VES and reliving ($r = .20$, $p = .047$), suggesting that people who tended to report a stronger sense of reliving also had higher scores on the VES; however, this correlation was not significant after correction for multiple comparisons. Similarly, only the VES positively correlated with participants' ratings of the intensity of the imagery in their autobiographical memories ($r = .30$, $p = .0029$). The Mental Rotation Test correlated negatively with the sense of reliving and the vividness of visual imagery, and the imagery questionnaires only sporadically correlated with each other.

Note that three key variables are all intercorrelated: People who tend to generate vivid visual images also tend to report a greater sense of reliving; people who have a higher score on the VES tend to generate more vivid visual imagery when they retrieve their memories, and they tend to experience a greater sense of reliving, as well. These findings raise the possibility that one's overall imagery ability affects the tendency to generate vivid visual images, which in turn affects the tendency to relive one's memories. Alternatively, these two variables could have independent effects on reliving.

Mediation analysis provides a way to examine these possibilities (Baron & Kenny, 1986). It allows us to assess the extent to which an independent variable exerts its effects on a dependent variable *through* a mediating variable. In this case, it allows us to assess the extent to which a general imagery ability (as measured by the VES) exerts its effects on reliving by affecting the tendency to generate vivid visual images during retrieval. Mediation analysis is appropriate when the mediator is a state variable (as it is here) and when the hypothesized mediator is correlated with the independent variable (as it is here; Wu & Zumbo, 2008).

In traditional mediation analysis, four criteria are used to provide evidence that a variable is a mediator (Baron & Kenny, 1986). First, we must show that the independent variable is a significant predictor of the dependent variable. In this case it is, as is shown above by the significant correlation between the VES and reliving. Next, we must show that the independent variable is a significant predictor of the hypothesized mediator. Again it is, as is shown above by the significant correlation between the VES and visual imagery. After that, we must show that the relationship between the VES and reliving diminishes when controlling for visual imagery; the results are consistent with full mediation when the relationship drops to 0. We assessed this criterion by conducting an analysis in which reliving was entered as the dependent variable, and visual imagery and VES score were entered as predictors. Visual imagery remained a significant predictor [$t(95) = 9.73$, $p < .0001$], but the VES did not [$t(95) = –0.21$, $p = .84$].

The results are presented in Fig. 1. The numbers on each line represent the regression coefficients calculated for each relationship. On the bottom line, the number outside parentheses represents the regression coefficient for the VES score when it was used as a predictor of reliving; the number inside parentheses is the regression coefficient after controlling for visual imagery.

These results are consistent with the traditional definition of a mediator. Current practice, however, uses a more powerful bootstrapping method to estimate the effect of a mediator and determine whether it is different from zero (Preacher & Hayes, 2008). We therefore conducted a mediation analysis using Hayes's (n.d.) SAS macro with 5,000 bootstrapping samples. The bias-corrected confidence interval did not cross 0 (95 % CI = .04–.18, point estimate = .11), again consistent with the idea that the VES exerts its effects on reliving through its effects on the tendency to generate visual imagery during recall.

As we noted above, these analyses depended on correlations calculated between subjects. This approach assumes that participants are using the scale as an absolute measure of imagery rather than as a relative measure of their own memories. To be more specific, most individuals have memories that vary in vividness. If participants are using the scale in a relative way (*this* memory is more vivid than *that* one, so I will give it a 5 instead of a 4), then we would have no reason to expect correlations between their average memory rating and measures of visual and spatial imagery, because each individual's scale would be centered around their own average level of imagery. We have several reasons to believe that this is not a concern. First, the instructions for the scale, and the scale

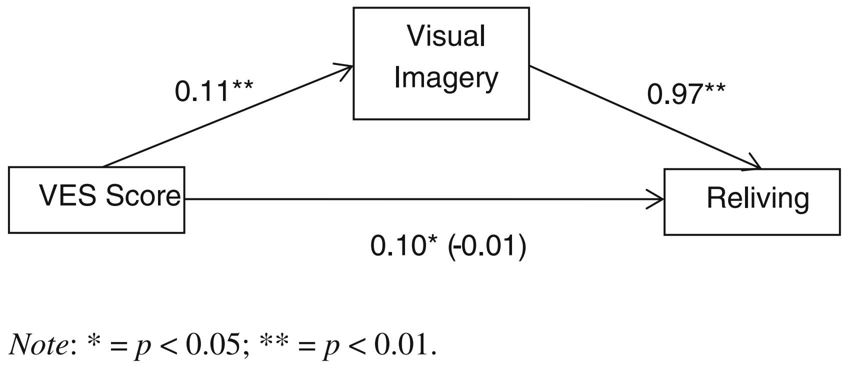

Fig. 1 Relationships between Visual Elaboration Scale (VES) score, visual imagery, and reliving. $^{*}p < .05$. $^{**}p < .01$

anchors, were absolute: A 7 for visual imagery, for instance, was defined as *as clearly as if it were happening right now*, and thus was anchored to perception and not to one's own internal use of visual imagery. One could argue that people might not have been following the instructions or attending to the anchors, but participants did seem willing to use solely the high or the low end of the scale (see Exp. 3 for an example), which is inconsistent with the notion that they were anchoring it around their own average level of imagery.

Another approach to this issue would involve using within-subjects correlations (Rubin et al., 2003). In this analysis, each participant contributes a correlation matrix rather than a mean. Each cell in the correlation matrix is correlated using the 16 memories that each person generated. This analysis can illustrate (e.g.) whether a particular *individual's* imagery ratings were correlated with his or her reliving ratings, as well as the extent to which that correlation varied across participants. In turn, this approach allowed us to ask whether visual imagery and reliving are linked in people with strong imagery abilities, but not in people with weaker imagery abilities. To address this question, we conducted multilevel modeling to examine the relations between reliving ratings, ratings of visual imagery during memory retrieval, and the imagery questionnaires. The reliving ratings were set as the dependent variable of interest; imagery ratings were nested within both participants and imagery questionnaire scores. We then tested for an interaction between each questionnaire and imagery to see whether the effect of imagery on reliving varied with imagery ability. We found no significant results (all Fs < 3.50, all ps > .05), though these results must be interpreted with caution because of the inherently low power involved in testing an interaction when multiple covariates have already been entered. We took a different approach to a similar question in Experiment 2.

Overall, the results of the between-subjects correlational analysis suggested a strong relation between visual imagery and reliving. They further suggested that cognitive style, as measured by the VES, might play a role in the relationship between visual imagery and memory. The mediation analyses supported this view.

Discussion

In this study, participants rated 15 memories on the AMQ and also completed questionnaires assessing their visual-imagery abilities. As in previous studies (Rubin et al., 2003), correlational analyses showed that people who tend to report strong visual imagery in their memories also tend to relive and believe those memories. None of the standard visual-imagery questionnaires showed a significant positive correlation with belief, however. Furthermore, with the exception of the VES, the standard visual-imagery questionnaires did not positively correlate with reliving, nor did they correlate with the ratings of visual imagery in the memories themselves. Mediation analysis suggested that participants' overall imagery ability exerted its effects on reliving by affecting participants' tendency to generate visual images during recall.

These results are inconsistent with the results of D'Argembeau and Van der Linden (2006), who found a significant relationship between VVIQ scores and the amount of visual and other sensory details in the memory. This difference is particularly striking, given that these authors used a version of the AMQ to collect their data. One possible explanation involves the types of cues that were used in each study. D'Argembeau and Van der Linden used broad cues that referred to a particular period of time (today, yesterday, a week ago, a year ago, etc.), whereas in our experiment we generally used concrete and imageable cues. We know that these kinds of cues tend to elicit specific memories rather than general ones (Williams, Healy, & Ellis, 1999). Thus, perhaps visual imagery and differences in visual imagery have a greater role to play when trying to move from a broad cue to a specific memory; when the cue is already specific, visual imagery might not be as important. (We are grateful to one of our reviewers for this suggestion.) Further investigations of cue type would help clarify this issue.

Why do visual-imagery questionnaires correlate so little with the key phenomenological properties of memory? There are several possibilities. First, as other work has shown (see Richardson, 1994, for a review), these questionnaires do not strongly correlate with each other, and they tap different aspects of imagery: The MRT focuses on the manipulation of spatial imagery, for instance, whereas the CVIQ asks about the ability to manipulate and alter visual images. Furthermore, these questionnaires do not capture every important aspect of visual imagery. Each of them asks whether participants *can* generate and manipulate vivid visual images; they do not ask whether participants typically do so when retrieving an autobiographical memory. In other words, participants vary not only in their ability to use visual imagery, but also in their tendency to use it—that is, in their cognitive styles. Of the four imagery tests that we used, only the VES touches on cognitive style, and it was the only test that showed significant positive correlations with key autobiographical memory variables. Specifically, the positive VES–reliving correlations suggest that visualizers have a higher degree of reliving. (The negative relationship between the MRT and other autobiographical measures is harder to explain. As we will note in Exp. 3, it is possible to have intact spatial ability in spite of poor visual imagery of autobiographical memory, so perhaps these abilities are independent, or even negatively correlated; see Kozhevnikov et al., 2005, for a similar argument.) To further explore the relation between visual-imagery tendencies and autobiographical memory, we examined the effects of cognitive style by examining the role of visual imagery in the sense of reliving in visualizers and verbalizers.

Experiment 2

Method

Participants, materials, and procedure The participants in our introductory participant pool were screened using the Visualizer–Verbalizer Cognitive Style Questionnaire (Kozhevnikov et al., 2005), a more recent measure that focuses on cognitive style. In this questionnaire, participants solve a series of problems, then are asked to describe the strategy that they used to solve each problem. Visual strategies are assigned a score of 2, and verbal strategies are given a score of 0; intermediate or mixed strategies are given a score of 1. Participants who were entirely visualizers or entirely verbalizers were invited to participate in the full experiment, which resulted in 53 participants (38 female, 15 male; mean age 19.1 ± 1.4). We had one group of 30 visualizers and another of 23 verbalizers.

As in the previous experiment, participants rated 15 memories on a version of the AMQ; the questions on this version are listed in Table 1. After the memory portion was over, we administered the VVIQ and the MRT. The procedure was otherwise the same as in Experiment 1.

Results

Table 4 presents the means and standard deviations, broken down by participant group. Since many of the distributions deviated from normality, we used Kruskal–Wallis tests to analyze the data. These analyses showed that verbalizers gave higher ratings for auditory imagery ($\chi^2 = 8.25$, $p = .041$), and were also more likely to say that the memory came to them in words ($\chi^2 = 4.01$, $p = .0452$). The mean ratings for visual imagery did not differ, however ($\chi^2 = 0.50$, $p = .48$), and no other variables were significant at the .05 level.

Table 4 Mean (with *SD*) ratings for visualizers and verbalizers

	Visualizers	Verbalizers
Reliving	4.88 (1.04)	5.33 (0.90)
Remember/know	5.87 (0.91)	5.84 (0.86)
Belief	5.86 (0.88)	5.84 (0.98)
Visual imagery	5.47 (0.87)	5.67 (0.89)
Setting	5.82 (0.78)	5.81 (0.93)
Auditory imagery	**3.51 (1.04)**	**4.49 (1.34)**
In words	**2.71 (1.68)**	**3.68 (1.77)**
Narrative coherence	4.59 (1.16)	5.10 (1.16)
Emotional arousal	3.39 (1.10)	3.94 (1.45)
Positive valence	4.22 (0.78)	4.54 (0.99)
Negative valence	3.12 (0.74)	3.15 (1.00)
Rehearsal	4.10 (1.11)	4.68 (1.25)
Age of memory (days)	1,201.67 (796.25)	1,555.97 (1,030.00)
VVIQ	2.56 (0.58)	2.23 (0.75)
MRT	15.37 (5.37)	14.91 (8.35)

Rows in bold were significantly different at $p < .05$

The differences in means indicate that the memories of visualizers and verbalizers have different phenomenological properties (though the differences were not strong). They do not indicate, however, whether these phenomenological properties play different roles in these groups. For instance, one might speculate that the vividness of visual imagery would predict the sense of reliving in visualizers, but auditory imagery might predict reliving in verbalizers.

To examine this question, we conducted a series of multiple regression analyses with reliving as the dependent variable. For the independent variables, we included the participant group (visualizers vs. verbalizers) as well as a subset of variables from the AMQ: specifically, visual imagery, emotional intensity, the extent to which the memory came in words, and auditory imagery. The first three variables were selected because they had been significant predictors of the sense of reliving in previous work (Rubin et al., 2003), and the last was selected because it differed significantly between the two groups, as noted above. We also included interaction terms to test for interactions between participant group and the selected AMQ variables. Finally, we reduced the model to the significant variables, except that if an interaction term was significant, we retained the main-effects term. In this way, we sought to refine the model in previous work and show whether it differed between subgroups. (An alternative approach would have involved entering all AMQ variables and their predictors, but this method—which would require entering 14 variables and 13 interaction terms—would be statistically unwieldy and difficult to interpret.)

The final model was statistically significant [R^2 = .54; $F(5, 47)$ = 10.93, $p < .0001$]. It contained four significant predictors: cognitive style [$t(47)$ = –2.52, p = .02], visual imagery [$t(47)$ = 2.91, p = .006], emotional intensity [$t(47)$ = 3.33, p = .002], and the Cognitive Style × Auditory Imagery interaction [$t(47)$ = –2.42, p = .02]. We found no main effect of auditory imagery, however [$t(47)$ = –0.37, p = .71]. Thus, the analysis indicated that auditory imagery was the only variable that played different roles in visualizers and verbalizers; visual imagery and emotional intensity did not. To further explore the difference, we calculated separate models of reliving for verbalizers and visualizers, entering the visual imagery and emotional intensity variables followed by the auditory imagery variable. We found that auditory imagery was a significant predictor of reliving in verbalizers [$t(19)$ = 2.56, p = .02], but not in visualizers [$t(25)$ = –0.93, p = .36].

To confirm these results, we used relative-importance analysis, which is a refinement of the usual multiple-regression approach. When predictors are intercorrelated, the usual β weights are harder to interpret, and their standard errors may be inflated, making it more difficult to detect significant predictors (see Kraha, Turner, Nimon, Zientek, & Henson, 2012, for discussion). This problem is particularly serious when researchers are trying to compare the relative contributions of different predictors to variance in a particular dependent variable. Relative-importance analysis was developed as a supplement to multiple regression that addressed this problem (see Tonidandel & LeBreton, 2011; Tonidandel, LeBreton, & Johnson, 2009). It shows the contribution that each variable makes to the overall R^2 (and whether that contribution is significantly different from the contribution of a randomly generated variable) after controlling for multicollinearity. Given the intercorrelations among our predictors, we used relative-importance analysis as a check to ensure that we had not omitted a significant predictor. The results indicated that we had not: The main effects that had been nonsignificant in the original analysis continued to be nonsignificant in the relative-weight analysis.

Discussion

In Experiment 1, we showed that measures of visual imagery did not correlate with measures of reliving and belief; the only exception came from a measure of cognitive style. Here, in Experiment 2, we examined this distinction further by comparing the autobiographical memories of visualizers and verbalizers. We found that visualizers and verbalizers provided nearly equal ratings for visual imagery and did not differ significantly in their ratings of reliving. Verbalizers, however, were more likely to say that their memory involved auditory imagery, and that it came to them in words. Furthermore, a significant interaction between cognitive style and auditory imagery showed that auditory imagery played different roles in visualizers and verbalizers. Further analysis showed that auditory imagery was a significant predictor of reliving in verbalizers, but not in visualizers.

Thus, the difference between verbalizers and visualizers does not seem to have anything to do with visual imagery at all. Several possible reasons could lie behind this finding. First, perhaps the visualizer–verbalizer distinction is simply not that meaningful, at least in the context of autobiographical memories. That is, perhaps imagery is so vital that all participants (at least, all participants who have visual imagery) use it when generating autobiographical memories, even if they do not use it on other tasks. As Table 4 shows, the verbalizers gave high ratings for visual imagery—their mean rating was a 5.7 out of 7, which is numerically (but not significantly) higher than that of the visualizers.

Alternatively, these findings may hint that the visualizer–verbalizer distinction needs to be refined. The verbalizers did differ from the visualizers in other ways—they reported a greater intensity of auditory imagery and were more likely to say that their memory came in words. Similarly, auditory imagery predicted reliving in verbalizers, but not in visualizers. Therefore, perhaps verbalizers are not simply people who tend to use verbal abilities alone; perhaps they are people who can use verbal abilities to *supplement* whatever visual imagery abilities they already have. This possibility is consistent with previous research showing that scores on visualizer–verbalizer questionnaires do not correlate with scores on the VVIQ (Kozhevnikov et al., 2005).

These results provide some insight into the role of visual imagery in autobiographical memory. In verbalizers, verbal abilities do not replace the role of visual imagery; they simply supplement it. Yet all participants—including the verbalizers—are able to use visual imagery to some degree. What about people who cannot use visual imagery at all? We attempted to address this question by examining the relations among autobiographical memory properties in people who had a visual imagery deficit without neurological disease or other evident impairment.

Experiment 3

Method

A complete absence of visual imagery is rare (Galton, 1880a, b; see Brewer & Schommer-Aikins, 2006, for an argument that Galton actually *under*estimated the prevalence of visual imagery in scientists). In Experiment 1 above, *all* of the participants reported visual imagery; none was at floor. Similarly, even the verbalizers in Experiment 2 above had some degree of visual imagery; again, none was at floor. Thus, out of the previous 121 participants, none had a complete absence of visual imagery. Other studies have yielded similar results. For example, in a norming study of 730 undergraduates (Kihlstrom, Glisky, Peterson, Harvey, & Rose, 1991), less than 3 % of participants reported little or no imagery (the precise number with no imagery was not reported).

Over the last several years, we have only been able to locate and test two participants who self-reported a total congenital absence of visual imagery. Both of these participants contacted us to seek more information after reading a previous article on a similar topic (Rubin & Greenberg, 1998). We report their data individually, as is often done in neuropsychological case studies.

Participants The first participant, G.S., was a female graduate student who was 27 years old at the time of testing. The second participant, N.B., was a 49-year-old female social worker with 16 years of education. Both participants reported that they had never had any visual imagery whatsoever, and neither had a history of neurological or psychiatric disease. Each participant was tested individually, and each provided informed consent.

Materials and procedure N.B. completed a battery of neuropsychological tests, consisting of the verbal portion of the Wechsler Adult Intelligence Scale–III (WAIS-III; Wechsler, 1997a), the Wechsler Memory Scale–III (WMS-III; Wechsler, 1997b), the Short Form California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 2000), and the Rey–Osterrieth Complex Figure Task (Meyers & Meyers, 1995). G.S. was unavailable for cognitive testing beyond the visual-imagery and autobiographical memory tasks described below.

As in the previous studies, the participants were asked to rate 15 memories with the AMQ. The participants were tested individually in university classrooms. They were read the printed instructions and asked to think of a memory associated with the word TREE. The experimenter reviewed each question briefly and answered any questions the participants had about it. The participants were then asked to recall a memory related to each of the 15 cue words and to rate each memory on the AMQ. The questions used in this study are marked with a “3” in Table 1.

The experimenter explained each rating scale and answered any questions that arose. The participants completed the questionnaire at their own pace. They were also given the VVIQ and the MRT.

Results

On the WAIS-III, N.B. obtained a verbal IQ of 103, which is within the average range. She performed one standard deviation above the mean on the Vocabulary, Similarities, and Information subtests, but one standard deviation below the mean on Arithmetic and Digit Span (see Table 5 for her full neuropsychological profile). On the WMS-III, N.B.’s performance was variable, but she had particular difficulty with visual memory. Her copy score on the Rey–Osterreith Figure Test was normal, but her immediate and delayed recall were both impaired.

Both participants scored at floor on the VVIQ. N.B. refused to take the MRT, saying she found it “impossible.” G.S. scored a 21.

On the AMQ, both participants always rated visual imagery at 1 (the bottom of the scale), so this variable was dropped from the analyses. In addition, G.S. always circled a 1 for auditory imagery, so this variable was excluded from the analysis of her data. Table 6 presents the means, standard deviations, and ranges for the remaining variables. It also includes z scores; for G.S., these are based on the results of our previous study (Rubin et al., 2003), and for N.B., they are based on a sample of 12 age- and education-matched controls. Variables with z scores larger than 1.96 are shown in bold.

Note that N.B.’s ratings for auditory imagery were abnormally low, though she did report auditory imagery for a few memories. Also, both G.S. and N.B. gave abnormally low ratings for “reliving”: Their mean scores were 2.5 and 2.0, respectively, and neither participant ever rated reliving higher than 5. Nevertheless, both participants tended to believe their memories: Their mean ratings were 6.1 and 6.4, respectively, which are not significantly different from the control mean of 5.8. Finally, both participants’ ratings for rehearsal—how often they had thought or talked about the memory—were far higher than the control mean.

Table 5 Neuropsychological profile of N.B.

Test	Score	Percentile	Interpretation
WAIS-III	103	58th	Average
Rey			
Copy	32	60th	Normal
Immediate recall	9	12th	Abnormal
Delayed recall	7	5th	Impaired
CVLT			
Trials 1–4 free recall	31	79th	
Short-delay free recall	8	50th	Average
Long-delay free recall	8	50th	Average
WMS-III			
Auditory immediate	108	70th	Average
Visual immediate	68	2nd	Low
Immediate recall	87	19th	Low average
Auditory delayed	120	91st	Superior
Visual delayed	78	7th	Borderline
Auditory recognition	110	75th	High average
General memory	103	58th	Average
Working memory	99	47th	Average

Table 6 Means for G.S. and N.B.

	G.S.			N.B.		
	Mean ± *SD*	Range	*Z* Score	Mean ± *SD*	Range	*Z* Score
Reliving	**2.50 ± 1.15**	**1–5**	**–2.91**	**2.00 ± 1.18**	**1–5**	**–3.07**
Remember/know	6.06 ± 1.18	4–7	0.57	5.79 ± 2.08	1–7	–0.58
Belief	6.06 ± 1.29	3–7	0.43	6.36 ± 1.08	3–7	–0.41
Visual imagery	–	–	N/A	–	–	N/A
Setting	4.56 ± 1.67	2–7	–1.72	**1.93 ± 1.00**	**1–4**	**–3.23**
Auditory imagery	–	–	N/A	**1.50 ± 0.76**	**1–3**	**–3.85**
In words	5.13 ± 1.15	3–7	1.25	5.71 ± 0.61	5–7	0.60
Story	4.56 ± 1.93	2–7	0.07	5.21 ± 1.31	1–6	1.05
Arousal	**1.25 ± 0.58**	**1–3**	**–3.74**	5.50 ± 1.79	1–7	–0.38
Rehearsal	**5.81 ± 1.33**	**3–7**	**2.96**	**6.43 ± 0.85**	**4–7**	**3.10**

What phenomenological properties are associated with reliving and belief in these two participants? We attempted to answer this question by calculating correlation matrices for each participant. The results for the sense of reliving were inconsistent: For G.S., all variables correlated with reliving at the .05 level (except "in words" and "emotional arousal"); for N.B., no variables did. Similarly, for belief, the analysis of G.S.'s memories showed that all variables correlated with her tendency to believe her memories (except "emotional arousal"); for N.B., the analysis revealed a significant correlation only between belief and narrative coherence—that is, whether the memory came as a coherent story.

Discussion

In this experiment, we examined autobiographical memories in two participants who reported a complete and congenital absence of visual imagery. Both participants reported a complete absence of visual imagery in their memories; they always rated visual imagery at 1, which is well outside the range for normal controls. Moreover, the unusual results are not limited to visual imagery. One of the two participants reported no auditory imagery whatsoever, and the other participant had very minimal auditory imagery.

The most intriguing results, however, involve the sense of reliving. Both participants had highly abnormal ratings for reliving—2.50 for G.S. and 2.00 for N.B.—that were well below the normal control range. These results are consistent with previous work showing that mental imagery is necessary (though not sufficient) for a strong sense of reliving (Rubin et al., 2003). What variables predicted the sense of reliving in these participants? Unfortunately, the data here were inconsistent: Most variables correlated with reliving for G.S., but none did for N.B. By contrast, both of these participants strongly believed in the veracity of their memories. Here again, however, the data did not provide consistent information about the factors that affect belief in individuals without imagery.

General discussion

We conducted three experiments to investigate the role of visual imagery in autobiographical memory. The first experiment attempted to determine whether participants' visual-imagery abilities affected their tendency to relive and believe in their memories. We found no significant relation between visual-imagery measures and measures of reliving and belief, except on a measure of cognitive style. We followed up on this finding in the second experiment by comparing the senses of reliving of autobiographical memories in verbalizers and visualizers. We found that both groups seemed to have rich autobiographical memories that came with visual imagery; however, the verbalizers were more likely to have memories that involved auditory imagery or came to them in words. Furthermore, auditory imagery predicted reliving in verbalizers, but not in visualizers. In the third experiment, we examined two people who had no visual imagery. We found that these individuals not only had a deficit of visual imagery; they also had an auditory-imagery deficit and a near-complete inability to relive their memories.

These experiments lead to several new conclusions about the role of visual imagery in autobiographical memory. First, individual differences in imagery ability do not seem to have an effect on participants' tendency to relive their memories, at least for the vast majority of people who have at least some visual-imagery ability. By itself, this result seems to suggest that imagery and reliving are unrelated, which runs contrary to the findings of previous studies. Further examination of the results suggests a different interpretation, however. We know that memories with a strong sense of reliving tend to come with vivid visual imagery, and we know that participants' visual-imagery abilities (as measured by imagery questionnaires) do not seem to be related to the vividness of the visual imagery in the memories themselves. One possibility is that the imagery questionnaires may not tap the abilities that are required for the generation of autobiographical images. The VVIQ, for instance, requires participants to generate and manipulate contrived visual images in a controlled and effortful way, whereas images in autobiographical memories can come spontaneously, even involuntarily, in response to a particular cue. Moreover, the VVIQ attempts to tap specific imagery abilities—movement, color, and so forth—that are difficult for many people to generate (Richardson, 1994). Thus, a person who could generate only a static image with minimal color might still have a very vivid autobiographical memory, but would not perform at ceiling on the VVIQ.

The only measure of imagery that correlated with reliving was the VES, a measure of cognitive style. This finding led us to design our second experiment, in which we examined the ways in which people with different cognitive styles experience their memories. We compared the autobiographical memories of visualizers (those who tend to use visual imagery to solve problems) with verbalizers (those who tend to rely on linguistic strategies instead). Note that a verbalizer is not someone who completely lacks visual imagery (such people are very rare), just someone who tends not to use such imagery to solve certain problems. Furthermore, the difference seems to involve visual *object* imagery; multimodal spatial imagery is a different ability (Kozhevnikov et al., 2002). Here we found that, in verbalizers, memories with a strong sense of reliving still involved visual imagery; they differed from those of visualizers because they involved other cognitive processes (specifically, auditory imagery) as well.

The results from the two imageless participants are particularly striking. In most individuals, visual imagery and reliving are strongly correlated, regardless of those individuals' visual-imagery abilities. It appears that individuals with abnormally low visual imagery have abnormally low reliving, as well. Note further that these participants' limitation was specific to visual imagery—that is, unlike blind participants (Ogden & Barker, 2001) or participants with visual-imagery loss that is secondary to brain damage (e.g., Ogden, 1993; Rubin & Greenberg, 1998), these participants had no other evident cognitive or perceptual impairment. This conclusion is subject to several important limitations, however. First, and most obviously, we must be cautious in the conclusions that we draw from a sample size of two. Second, these individuals did not just lack visual imagery—they had abnormal auditory imagery, as well. Therefore, we cannot say for sure whether visual imagery alone is responsible for the weak sense of reliving that we observed in these participants. Nevertheless, it is striking that both sensory imagery and the sense of reliving were so abnormal in these participants.

These two cases raise other fascinating questions. Does the absence of sensory imagery lead to any other deficit, aside from a decreased sense of reliving? Do these individuals have imagery deficiencies in other modalities as well? Do they have difficulty with everyday visual tasks? What about other aspects of their memories? Is it possible that their imagery deficit actually confers a benefit? We know, for instance, that intrusive visual images play a role in a range of psychiatric conditions (see Holmes & Mathews, 2010, for a review), including social phobia (Hackmann, Clark, & McManus, 2000). Other research has shown that disrupting these visual images can prevent or alleviate the development of intrusive memories (e.g., Deeprose, Zhang, DeJong, Dalgleish, & Holmes, 2012). Are people with no visual imagery naturally resistant to these conditions, or would they experience them in other ways? Are these disorders in some way disorders of memory, or even disorders of reliving? Unfortunately, given the rarity of the condition, these answers will be difficult to obtain.

Finally, all of the experiments reported here had noteworthy limitations. In each experiment, we collected memory data using the Autobiographical Memory Questionnaire. This approach has several advantages—for instance, it allowed us to collect data on the phenomenological properties of a large number of memories. It did not, however, allow us to collect the *content* of those memories; we did not ask our participants to write down their memories so that we could analyze them later. We do not believe that this is a significant limitation; after all, we were interested in the phenomenological properties of these memories, and the participant is the only person who has access to this information. Furthermore, even if we had asked participants to transcribe their memories, it would not necessarily be easy to determine whether a particular detail was truly visual in nature. (For instance, if a participant remembers seeing a red, white, and blue American flag, is she visualizing the colors, or is she accessing nonvisual semantic knowledge about the flag's colors? She is the only person who has any insight into this question.) That said, we do believe that different cues can elicit different kinds of autobiographical memories, and we used only one cue type here. We are therefore conducting further studies to examine the interaction between imagery ability and cue type; however, the data presented here suggest that visual imagery is a vital and irreplaceable component of vivid autobiographical recall.

Author note This research was supported by a summer research stipend from the College of Charleston to D.L.G. The authors thank Lauren Deasy for assistance with participant testing, and David Rubin for sharing some of the data used in Experiment 1.

Appendix

Each of the questions below appeared in at least one experiment. The specific questions used in a particular experiment are noted in Table 1.

For questions a–g, the scales ranged from 1 (*not at all*), through 3 (*vaguely*) and 5 (*distinctly*), to 7 (*as clearly as if it were happening right now*).

a. As I remember the event, I feel as though I am *reliving* the original event.
b. As I remember the event, I can *hear* it in my mind.
c. As I remember the event, I can *see* it in my mind.
d. As I remember the event, I or other people are *talking*.
e. As I remember the event, I know its *spatial layout*.
f. As I remember the event, I can feel now the *emotions* that I felt then.
g. As I remember the event, I can recall the *setting* where it occurred.

For questions h–n, the scales ranged from 1 (*not at all*), through 3 (*vaguely*) and 5 (*distinctly*), to 7 (*as much as any memory*).

h. Sometimes people know something happened without being able to remember it. As I think about the event, I can actually *remember* it rather than just *know* it happened.
i. As I remember the event, it comes to me *in words*.
j. As I remember the event, I feel that I travel *back to the time when it happened*, that I am a subject in it again, rather than an outside observer tied to the present.
k. As I remember the event, it comes to me as a coherent *story* or episode and not as an isolated fact, observation, or scene.
l. While remembering the event, the emotions I feel are *positive*.
m. While remembering the event, the emotions I feel are *negative*.
n. This memory is *significant* for my life because it imparts an important message for me or represents an anchor, critical juncture, or a turning point.

The remaining questions had unique scales:

o. 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. (Scale: 1 = *100 % imaginary*, 7 = *100 % real*)
p. Since it happened, I have thought or talked about this event. (Scale: 1 = *not at all*, 7 = *as often as any event in my life*)
q. To the best of your knowledge, is the memory of an event that occurred once at one particular time and place, a summary or merging of many similar or related events, or for events that occurred over a fairly continuous extended period of time lasting more than a day? (Scale: 1 = *once*, 2 = *merging*, 3 = *extended*)

Responses to this last question were recoded to produce two scales. *Specific* had a value of 1 if the participant judged the memory to take place within a single day and 0 if it took longer. *Merged/extended* had a value of 0 if the event lasted longer than a day and was extended in a fairly continuous manner over a period of time, and 1 if it was the merging of many discrete events.

r. *Please date the memory (month/day/year) as accurately as you can. Please fill in a month, day, and year even if you must estimate. If the memory extended over a period of time, report the approximate middle of the period.

References

Baddeley, A. D. (1992). What is autobiographical memory? In M. A. Conway, D. C. Rubin, H. Spinnler, & W. A. Wagenaar (Eds.), *Theoretical perspectives on autobiographical memory* (pp. 13–29). Dordrecht, The Netherlands: Kluwer.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173–1182. doi:10.1037/0022-3514.51.6.1173

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corp.

Brewer, W. F. (1988). Memory for randomly sampled autobiographical events. In U. Neisser & E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to the study of memory* (pp. 21–90). Cambridge, UK: Cambridge University Press.

Brewer, W. F. (1996). What is recollective memory? In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 19–66). Cambridge, UK: Cambridge University Press.

Brewer, W. F., & Pani, J. R. (1996). Reports of mental imagery in retrieval from long-term memory. *Consciousness and Cognition, 5,* 265–287.

Brewer, W. F., & Schommer-Aikins, M. (2006). Scientists are not deficient in mental imagery: Galton revised. *Review of General Psychology, 10,* 130–146.

Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition, 5,* 73–99. doi:10.1016/0010-0277(77)90018-X

Cabeza, R., & St. Jacques, P. (2007). Functional neuroimaging of autobiographical memory. *Trends in Cognitive Sciences, 11,* 219–227. doi:10.1016/j.tics.2007.02.005

Clark, A., Nash, R. A., Fincham, G., & Mazzoni, G. (2012). Creating non-believed memories for recent autobiographical events. *PLoS ONE, 7,* e32998. doi:10.1371/journal.pone.0032998

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107,* 261–288. doi:10.1037/0033-295X.107.2.261

Crovitz, H. F., & Schiffman, H. (1974). Frequency of episodic memories as a function of their age. *Bulletin of the Psychonomic Society, 4,* 517–518.

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition, 15,* 342–350. doi:10.1016/j.concog.2005.09.001

Deeprose, C., Zhang, S., DeJong, H., Dalgleish, T., & Holmes, E. A. (2012). Imagery in the aftermath of viewing a traumatic film: Using cognitive tasks to modulate the development of involuntary memory. *Journal of Behavior Therapy and Experimental Psychiatry, 43,* 758–764.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). *California Verbal Learning Test-II*. San Antonio, TX: Pearson.

Eardley, A. F., & Pring, L. (2006). Remembering the past and imagining the future: A role for nonvisual imagery in the everyday cognition of blind and sighted people. *Memory, 14,* 925–936.

Galton, F. (1880a). Mental imagery. *Fortnightly Review, 28,* 312–324.

Galton, F. (1880b). Statistics of mental imagery. *Mind, 5,* 301–318.

Gordon, R. (1949). An investigation into some of the factors that favour the formation of stereotyped images. *British Journal of Psychology, 39,* 156–167.

Greenberg, D. L., Eacott, M. J., Brechin, D., & Rubin, D. C. (2005). Visual memory loss and autobiographical amnesia: a case study. *Neuropsychologia, 43,* 1493–1502.

Greenberg, D. L., & Rubin, D. C. (2003). The neuropsychology of autobiographical memory. *Cortex, 39,* 687–728.

Hackmann, A., Clark, D. M., & McManus, F. (2000). Recurrent images and early memories in social phobia. *Behaviour Research and Therapy, 38,* 601–610.

Hayes, A. F. (n.d.). INDIRECT [Computer software]. Retrieved from http://afhayes.com/spss-sas-and-mplus-macros-and-code.html

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review, 30,* 349–362.

Hyman, I., & Pentland, J. (1996). The role of mental imagery in the creation of false childhood memories. *Journal of Memory and Language, 35,* 101–117.

James, W. (1950). *The principles of psychology (Vol. 1)*. New York, NY: Dover. Original work published 1890.

Kihlstrom, J. F., Glisky, M. L., Peterson, M. A., Harvey, E. M., & Rose, P. M. (1991). Vividness and control of mental imagery: A psychometric analysis. *Journal of Mental Imagery, 15,* 133–142.

Kozhevnikov, M., Hegarty, M., & Mayer, R. E. (2002). Revising the visualizer–verbalizer dimension: Evidence for two types of visualizers. *Cognition and Instruction, 20,* 47–77.

Kozhevnikov, M., Kosslyn, S., & Shephard, J. (2005). Spatial versus object visualizers: A new characterization of visual cognitive style. *Memory & Cognition, 33,* 710–726. doi:10.3758/BF03195337

Kraha, A., Turner, H., Nimon, K., Zientek, L. R., & Henson, R. K. (2012). Tools to support interpreting multiple regression in the face of multicollinearity. *Frontiers in Psychology, 3*(44), 1–16. doi:10.3389/fpsyg.2012.00044

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging, 17,* 677–689.

Loftus, E. F., & Pickrell, J. (1995). The formation of false memories. *Psychiatric Annals, 25,* 720–724.

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology, 64,* 17–24.

Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of Educational Psychology, 95,* 833–846.

Mazzoni, G., & Kirsch, I. (2002). Autobiographical memories and beliefs: A preliminary metacognitive model. In T. J. Perfect & B. L. Schwartz (Eds.), *Applied metacognition* (pp. 121–145). Cambridge, UK: Cambridge University Press.

Meyers, J. E., & Meyers, K. R. (1995). *Rey complex figure test and recognition trial*. Lutz, FL: Psychological Assessment Resources.

O'Connor, M., Butters, N., Miliotis, P., Eslinger, P., & Cermak, L. S. (1992). The dissociation of anterograde and retrograde amnesia in a patient with herpes encephalitis. *Journal of Clinical and Experimental Neuropsychology, 14,* 159–178.

Ogden, J. A. (1993). Visual object agnosia, prosopagnosia, achromatopsia, loss of visual imagery, and autobiographical amnesia following recovery from cortical blindness: Case M.H. *Neuropsychologia, 31,* 571–589.

Ogden, J. A., & Barker, K. (2001). Imagery used in autobiographical recall in early and late blind adults. *Journal of Mental Imagery, 25,* 107–130.

Otgaar, H., Scoboria, A., & Smeets, T. (2013). Experimentally evoking nonbelieved memories for childhood events. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 717–730. doi:10.1037/a0029668

Peters, M., Laeng, B., Latham, K., Jackson, M., Zaiyouna, R., & Richardson, C. (1995). A redrawn Vandenberg and Kuse Mental Rotations Test: Different versions and factors that affect performance. *Brain and Cognition, 28,* 39–58.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40,* 879–891. doi:10.3758/BRM.40.3.879

Richardson, A. (1994). *Individual differences in imaging: Their measurement, origins, and consequences*. Amityville, NY: Baywood.

Rubin, D. C. (2006). The basic-systems model of episodic memory. *Perspectives on Psychological Science, 1,* 277–311. doi:10.1111/j.1745-6916.2006.00017.x

Rubin, D. C., & Greenberg, D. L. (1998). Visual memory-deficit amnesia: A distinct amnesic presentation and etiology. *Proceedings of the National Academy of Sciences, 95,* 5413–5416.

Rubin, D. C., Schrauf, R. W., & Greenberg, D. L. (2003). Belief and recollection of autobiographical memories. *Memory & Cognition, 31,* 887–901.

Scoboria, A., Mazzoni, G., Kirsch, I., & Relyea, M. (2004). Plausibility and belief in autobiographical memory. *Applied Cognitive Psychology, 18,* 791–807.

Slee, J. A. (1980). Individual differences in visual imagery and the retrieval of visual appearances. *Journal of Mental Imagery, 4,* 93–114.

Spreng, R. N., Mar, R. A., & Kim, A. S. N. (2009). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: A quantitative meta-analysis. *Journal of Cognitive Neuroscience, 21,* 489–510. doi:10.1162/jocn.2008.21029

Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: A meta-analysis. *Neuropsychologia, 44,* 2189–2208.

Tonidandel, S., & LeBreton, J. M. (2011). Relative importance analysis: A useful supplement to regression analysis. *Journal of Business Psychology, 26,* 1–9.

Tonidandel, S., LeBreton, J. M., & Johnson, J. W. (2009). Determining the statistical significance of relative weights. *Psychological Methods, 14,* 387–399.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26,* 1–12. doi:10.1037/h0080017

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills, 47,* 599–601.

Wechsler, D. (1997a). *Wechsler Adult Intelligence Scale—WAIS III* (3rd ed.). San Antonio, TX: Psychological Corp.

Wechsler, D. (1997b). *WMS-III: Wechsler Memory Scale* (3rd ed.). San Antonio, TX: Psychological Corp.

Williams, J. M. G., Healy, H. G., & Ellis, N. C. (1999). The effect of imageability and predictability of cues in autobiographical memory. *Quarterly Journal of Experimental Psychology, 52A,* 555–579.

Wilson, M. (1988). MRC Psycholinguistic Database: Machine-usable dictionary, version 2.00. *Behavior Research Methods, Instruments, & Computers, 20,* 6–10. doi:10.3758/BF03202594

Wu, A. D., & Zumbo, B. D. (2008). Understanding and using mediators and moderators. *Social Indicators Research, 87,* 367–392.