Remember When?
Henry L. Roediger III, *et al.*
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A gallery of knots. (**A**) The bow helps hold the dress together. The braid covers the buttons. (**B**) Tapestry (actually an embroidery) that encodes information. (**C**) Loops and knots formed by merging of defect lines created by colloidal particles in liquid crystals. Tkalec *et al*. used laser tweezers to manipulate the particles and lines, which causes the "Saturn ring" defects surrounding the particles to merge and tangle. (**D**) Catenated DNA minicircles in the mitochondria of *Leishmania tarentolae*. Like defect lines, they too are linked. [Photo in (D) courtesy of L. Simpson (*5*)]

knots. Although the winding of the director is somewhat more subtle than in water flow (because of the symmetries of the nematic phase), the presence of these lines implies an arrangement of molecular orientation in the surrounding space. The tied knots and images indicate only a section of the complexity of the bulk structure. It is not just the vortices that are tangled or the defect lines that are knotted; it is the whole surrounding medium—that is, a knotted field is created. Tkalec *et al*. demonstrate that the knotting of this field can be exquisitely controlled to create all possible knots and links between the colloidal inclusions.

These general structures are apparently only realizable in the twisted-cell geometry. It is an open question whether these knots can be tied and untied by switching the boundary conditions locally, for example, by applying an electric field to change the chiral twist. Not long ago, it was demonstrated (*2*) that some knots could be tied in light fields through an ingenious method of phase manipulation; in this case, the vortices are lines of complete darkness where the electromagnetic field vanishes.

Compare the links and knots formed by Tkalec *et al*. to the intricate linking of kinetoplast DNA (see the figure, panel D). The linking of the minicircles there is certainly not random, but its purpose is still somewhat of a mystery; it has been shown that minicircles play an important role in gene editing (*3*). Perhaps experimentally controlled particle linking could be used to control catalysis or modify binding sites in nonbiological applications. The tools developed by Tkalec *et al*. pave the path to these sorts of geometric and topological controls. It is intriguing to consider the possibility of marrying the two knotted fields, light and liquid crystals, to develop an entire new set of mathematical constructs (*4*) and potential devices. Can results in knot theory be discovered experimentally and systematically with these defect arrays? Not if we don't tie!

References

1. U. Tkalec, M. Ravnik, S. Čopar, S. Žumer, I. Muševič, *Science* **333**, 62 (2011).
2. M. R. Dennis, R. P. King, B. Jack, K. O'Holleran, M. J. Padgett, *Nat. Phys.* **6**, 118 (2010).
3. J. Shlomai, *Curr. Mol. Med.* **4**, 623 (2004).
4. N. A. Baas, *Eur. Phys. J. Spec. Top.* **178**, 25 (2009).
5. L. Simpson, A. Da Silva, *J. Mol. Biol.* **56**, 443 (1971).

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NEUROSCIENCE

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Group interactions can have both negative and positive impacts on memory.

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Philosophers, psychologists, and neuroscientists usually consider remembering to be a solitary activity. We envision the lone rememberer, lost in contemplation like Rodin's *Thinker*, recalling his past. In memory experiments, thousands of subjects have sat alone in front of computers or memory drums (older devices designed to present information), or have lain inside giant magnets, duly recollecting events of their lives. We have learned much about remembering from their efforts. However, this tradition of research fails to capture a prominent characteristic of everyday remembering: its social aspects. That is, people tend to reminisce in groups—whether at family dinners, reunions, or other social engagements. On page 108 of this issue, Edelson *et al*. (*1*) offer new insight into the social aspects of memory, reporting on the first experiments to examine the neural underpinnings of how memories can change when an individual is exposed to the recollections of others. They show that activity in two brain regions involved in memory—the hippocampus and the amygdala—can vary, depending on how one person's memory has been shaped by interacting with others.

Consider a person telling a story to acquaintances at a party. Storytellers routinely (and knowingly) embellish their stories in order to better capture an audience's interest. Past research, however, has shown that storytellers can readily incorporate these seemingly inconsequential embellishments into their own memory of the original event (*2*). The situation becomes even more complex when a storyteller recollects an event in the presence of others who were present during the event. In this situation, the vari-

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ous players contribute to the group recollection. Each can relate events accurately, in turn updating and reinforcing the memories of the storyteller and other group members. But some members of the group may erroneously recall some details, which will tend to infect the storyteller's record of events with distortions (or vice versa); psychologists call this process social contagion (*3*, *4*).

These social aspects of remembering have recently come under renewed scrutiny by cognitive and social psychologists, who have noted both these positive and negative effects (*5*, *6*). Psychologists have tended to note the negative effects more than the positive ones, however, perhaps because errors can have important societal implications, such as erroneous eyewitness testimony in courts of law (*7*).

Memory conformity is the general term for these positive and negative effects. Psychologists distinguish between private conformity (truly believing the conforming response to be one's own) and public conformity (going along with the group, even if you privately believe the group is wrong). Social psychologists have worked out techniques to distinguish between public and private conformity, and cognitive psychologists have applied them to the study of memory. Edelson *et al*. extend these efforts by using functional magnetic resonance imaging to record the brain activity of 30 adults who viewed a documentary-style movie and then were tested on their memories of the movie over a 2-week period. The researchers intentionally tried to induce memory errors in some subjects by telling them what others recalled about the movie; they exposed other subjects to randomized "recollections."

Their findings offer insight into how social interaction can alter memories. In particular, they provide evidence for separate neural bases for shorter-lived "transient" memory errors, which may reflect public conformity, and longer-lived "persistent" memory errors, which may reveal private conformity. Specifically, the researchers observed greater neural activation in the hippocampus for items that showed persistent memory errors (private conformity) than for items that displayed transient errors (possible public conformity). They were also able to distinguish between conformity elicited by social influences (being exposed to other people, or at least their faces) and conformity produced by nonsocial methods (being exposed to computer-generated responses to questions on a test). The investigators observed robust activation of the amygdala in subjects who displayed social conformity (responding when influenced by other people's responses); in contrast, they observed less activation in subjects displaying nonsocial conformity (responding to computer-generated responses). This finding mirrored behavioral data suggesting that greater conformity occurred under social pressure. In addition, a control experiment showed that amygdala activation did not seem to reflect emotional arousal but was instead attributable to the social nature of the influence.

Think again. Memories recalled when alone can change if shared with others. Barry Flanagan's *Thinker on Rock* sits on the campus of Washington University in St. Louis, Missouri.

These results are in some ways surprising. For instance, the observation that amygdala activation occurred disproportionately on occasions when social influence consistently changed memory, or changed belief in recently perceived events, suggests a previously unrecognized function for this brain region. But full understanding of this finding awaits future research.

Edelson *et al*. were concerned with memory conformity, but there are also other types of deleterious social influence from remembering in groups. In particular, when people all learn common information and then are tested, either individually or in groups (usually three people), a paradoxical effect called collaborative inhibition emerges (*8*). The total number of events remembered by the group exceeds that of individuals. However, when researchers compare the recollections of a group that has had collaborative discussions to the recollections of three people acting individually (a nominal group), the actual group recalls fewer events than the nominal group. This outcome is not due to social loafing—the tendency for people in groups to work less hard than they do when individual performance is measured. Rather, the collaborative setting seems to disrupt the retrieval processes that individuals use when they are recalling in isolation (*8*, *9*). To date, the only reported exception to this finding involves collaborative groups made up of experts on a topic; then the groups do better than the individuals (*10*). A target for future research is to see whether the generally deleterious effect of social remembering has a neural basis similar to that of memory conformity.

Social effects on remembering can be positive as well as negative. Indeed, memory conformity may typically be beneficial. If one individual in a group forgets critical information (about food resources or dangers, for instance), then it is wise to get an updated memory from another group member. In experiments that have examined social influence when others provide accurate information, the effects are strongly positive (*11*). As with perceptual illusions, most memory illusions probably reveal adaptive processes that can sometimes undermine rather than support accurate remembering (*12*). Whether the positive effects of social influence have the same neural bases as the negative effects also awaits future investigation. However, we predict that positive memory conformity will have the same bases as the negative effects, because both reflect updating of individual memory by social means.

The study of individual remembering is more than 125 years old, whereas the study of the social aspects of remembering is relatively young. Edelson *et al*. provide a promising first step in delineating the neural underpinnings of memory conformity, an important issue in the social psychology of remembering.

References

1. M. Edelson *et al*., *Science* **333**, 108 (2011).
2. E. J. Marsh, B. Tversky, *Appl. Cogn. Psychol.* **18**, 491 (2004).
3. F. C. Bartlett, *Remembering: A Study in Experimental and Social Psychology* (Macmillan, New York, 1932).
4. H. L. Roediger 3rd, M. L. Meade, E. T. Bergman, *Psychon. Bull. Rev.* **8**, 365 (2001).
5. M. S. Weldon, in *The Psychology of Learning and Motivation*, D. L. Medin, Ed. (Academic Press, San Diego, CA, 2000), vol. 40, pp. 67–120.
6. M. Ross, C. W. Blatz, E. Schryer, in *Learning and Memory: A Comprehensive Reference*, H. L. Roediger, Ed. (Elsevier, Oxford, 2008), vol. 2, pp. 911–926.
7. E. F. Loftus, *Learn. Mem.* **12**, 361 (2005).
8. M. S. Weldon, K. D. Bellinger, *J. Exp. Psychol. Learn. Mem. Cogn.* **23**, 1160 (1997).
9. S. Rajaram, L. P. Pereira-Pasarin, *Perspect. Psychol. Sci.* **5**, 649 (2010).
10. M. L. Meade *et al*., *Memory* **17**, 39 (2008).
11. E. F. Loftus, D. G. Miller, H. J. Burns, *J. Exp. Psychol. Hum. Learn.* **4**, 19 (1978).
12. H. L. Roediger, K. B. McDermott, in *The Oxford Handbook of Memory*, E. Tulving, F. I. M. Craik, Eds. (Oxford Univ. Press, Oxford, 2000), pp. 149–162.

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