Journal of Experimental Psychology:
Learning, Memory, and Cognition
2012, Vol. 38, No. 1, 218–228


0278-7393/11/$12.00 DOI: 10.1037/a0025161

RESEARCH REPORT

# Dynamic Search and Working Memory in Social Recall

Thomas T. Hills and Thorsten Pachur
University of Basel

What are the mechanisms underlying search in social memory (e.g., remembering the people one knows)? Do the search mechanisms involve dynamic local-to-global transitions similar to semantic search, and are these transitions governed by the general control of attention, associated with working memory span? To find out, we asked participants to recall individuals from their personal social networks and measured each participant's working memory capacity. Additionally, participants provided social-category and contact-frequency information about the recalled individuals as well as information about the social proximity among the recalled individuals. On the basis of these data, we tested various computational models of memory search regarding their ability to account for the patterns in which participants recalled from social memory. Although recall patterns showed clustering based on social categories, models assuming dynamic transitions between representations cued by social proximity and frequency information predicted participants' recall patterns best—no additional explanatory power was gained from social-category information. Moreover, individual differences in the time between transitions were positively correlated with differences in working memory capacity. These results highlight the role of social proximity in structuring social memory and elucidate the role of working memory for maintaining search criteria during search within that structure.

*Keywords:* working memory, executive function, search, social networks, individual differences

Recalling people we know is a key cognitive function. We recruit social memories to judge the frequency of a myriad of social events—ranging from diseases to consumer preferences (e.g., Hertwig, Pachur, & Kurzenhäuser, 2005; Pachur, Hertwig, & Rieskamp, in press)—to assess our relative positions in the social environment (e.g., with regard to happiness or income; Boyce, Brown, & Moore, 2010; Brown, Gardner, Oswald, & Qian, 2008), to establish whom we can trust to cooperate in future interactions (Stevens & Hauser, 2004), and to access others even beyond our own social circles (Kleinberg, 2000; Milgram, 1967). But how do we search social memory? And does this search reflect a general attentional process, as has been suggested for search in semantic memory?

Whereas social memory has often been studied relatively independently from other memory research, here we test the thesis that similar processes might apply for search in social memory as apply to search in semantic memory. Our argument involves two claims. First, search in social memory should dynamically transition between local and global search criteria (as implemented in models of semantic memory search, such as search of associative memory [SAM]; Raaijmakers & Shiffrin, 1981). Second, as proposed for a generalized cognitive search process (Hills, Todd, & Goldstone, 2008, 2010), transitions between local and global search criteria should recruit the general control of attention as measured by working memory capacity (WMC). This latter claim is also related to the proposal that working memory is involved in the guidance of strategically controlled search in long-term semantic memory (Unsworth & Engle, 2007).

The study presented here investigates these hypotheses by modeling the patterns in which people recall their social contacts and by investigating to what extent aspects of this search process correlate with WMC. Before describing our study in more detail, we briefly review previous research on the structure of social memory and highlight parallel ideas in research on semantic memory. We then describe in greater detail our hypotheses concerning dynamic search policies in social memory and the role of executive processing and working memory.

## Search in Social Memory

How is social memory structured? And how do people navigate this internal structure? A common approach to studying social memory is to ask participants to "name the people you know" and to analyze the pattern in which these individuals are retrieved (e.g., Bond, Jones, & Weintraub, 1985; Brewer, 1995; Fiske, 1995).[1] A typical finding in these studies is that individuals are recalled in clusters of related individuals (Bond et al., 1985). Several factors have been proposed to drive this clustering: The people we know

This article was published Online First August 22, 2011.

Thomas T. Hills and Thorsten Pachur, Department of Psychology, University of Basel, Basel, Switzerland.

This research was supported by Swiss National Science Foundation Grant 100014 130397/1 awarded to Thomas T. Hills.

Correspondence concerning this article should be addressed to Thomas T. Hills, Department of Psychology, University of Basel, Missionsstrasse 64A, 4055 Basel, Switzerland. E-mail: thomas.hills@unibas.ch

[1] An alternative approach is to present participants with various hypothesized structuring variables (e.g., locations, role relationships) as retrieval cues and to compare these cues in terms of their effectiveness in eliciting recall (e.g., Brewer & Garrett, 2001; Brewer, Garrett, & Rinaldi, 2002).

may be organized in terms of individual characteristics (such as gender, age, or hair color), spatial or geographical location, alphabetic similarity of their names, or factors concerning social relations (cf. Brewer, 1993; Brewer, Rinaldi, Mogoutov, & Valente, 2005; Fiske, 1995). Of these possible factors, structuring in terms of social relations seems to account for the data best (see Brewer et al., 2005).

However, there are at least two different ways in which social relations could influence social recall. On the one hand, people may use *categorical* search policies, in which individuals first think about a social category (e.g., one's family), and then recall individuals "locally" from within this category, before switching to another social category (e.g., Bond & Brockett, 1987; Fiske, 1995; for a test of Fiske's taxonomy of categories, see Brewer et al., 2005). Alternatively, recall may reflect an *associative* search policy, which recruits information about the social proximity among the individuals themselves (e.g., Brewer, 1995; Brewer et al., 2005). Such an associative policy implies a search through a cognitive representation of a person's social network, with individuals connected and retrieved together not because they share the same category but because they know one another.

In this article, we use the computational tools developed for the study of semantic memory to study the search processes when people navigate social memory. Previous investigations have tended to consider social memory as relatively separate from recall of nonsocial material (Bond et al., 1985; Brewer, 1995; Fiske, 1995; but see Bahrick, Bahrick, & Wittlinger, 1975; Williams & Hollan, 1981). Because of its episodic character (Tulving, 2002) and potential differences in functionality (cf. Klein, Cosmides, Tooby, & Chance, 2002), social memory may indeed not completely overlap with other forms of memory, such as semantic memory. However, as we describe next, categorical and associative search policies have also been discussed in the context of semantic memory.

The distinction between categorical and associative forms of search was proposed for semantic memory (Pollio & Gerow, 1968) to account for clustering in patterns of recall found in Bousfield and Sedgewick's (1944) pioneering studies of free recall from natural categories. In this context, categorical recall refers to search based on group membership ("dog" is in the category "pets") and associative recall to search based on item-level associations ("dog" is similar to "cat," which is similar to "lion," and so on). The contrast between categorical and associative recall is still currently discussed. For instance, the notion of categorical recall is central to the *cluster switching hypothesis* (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998) proposed in the context of category fluency tasks, in which people are instructed, for instance, to "say all the animals you can think of." According to this hypothesis, people identify a subcategorical cluster (e.g., "pets"), harvest items locally from within this cluster, and then make a global transition to a new cluster (e.g., "birds"; see also Gruenewald & Lockhead, 1980). Alternatively, the associative character of search is a common assumption in many prominent memory frameworks, such as SAM (Raaijmakers & Shiffrin, 1981) and Adaptive Control of Thought—Rational (ACT-R; Anderson, 1993). Although authors have speculated about and found initial evidence for the combined influence of categorical and associative factors in social memory (e.g., Bond & Brockett, 1987; Brewer et al., 2005; Fiske, 1995), no prior studies have tested this possibility using cognitive modeling of the underlying retrieval mechanisms.

A further potential, and rather general, determinant of recall noted in many models of semantic memory (e.g., Anderson, 1993; Raaijmakers & Shiffrin, 1981) is the frequency with which an item—or a network member—is encountered (Brewer, 1995; Murray & Forster, 2004): Items that are more commonly encountered should be more easily accessed from long-term memory (Anderson & Schooler, 1991). Note that these three factors—categorical, associative, and frequency—are likely to be interrelated in social memory: People belonging to a particular social group (e.g., one's family) are likely to know each other. Moreover, different social groups may differ in terms of the temporal pattern of one's contacts to them: We may see members of a local club only once a week but see our partner on a daily basis. Because of these interdependencies between categorical, associative, and frequency factors, previous analyses of social recall were not always able to disentangle the individual influences of these factors (e.g., Fiske, 1995; but see Brewer et al., 2005; Brewer & Yang, 1994).

## The Dynamic Nature of Recall and the Role of Working Memory

In addition to which factors structure social memory, it is also unclear how these factors are used during search. Specifically, it has been proposed that search is governed by a dynamic process, where search can switch between different search criteria (that activate different representational structures) over time. According to this view, search may transition from a local focus (with recall based on inter-item similarity) to a global focus (based on frequency) as the content of local areas becomes depleted (Raaijmakers & Shiffrin, 1981; Troyer et al., 1998). In the context of social memory, search might thus switch between a local cue—such as social-category or social-proximity—and a global cue—such as frequency.

If search follows a dynamic process, what components of cognitive control might govern transitions between local and global criteria? One proposal is that a key role is played by working memory and attentional control to maintain cues to guide local aspects of search. Rosen and Engle (1997) presented evidence that cluster switching in the animal fluency task ("name all the animals you can think of") was governed by WMC (Kane & Engle, 2000; Unsworth & Engle, 2007). In their study, clusters were defined as items that were recalled in close temporal succession. Using this definition, Rosen and Engle found that individuals with higher WMC produced more items and showed larger clusters of related items than individuals with lower WMC. However, because this work used discontinuities in inter-item retrieval times to define clusters, the role of search criteria underlying these transitions was left unexplored.

Rosen and Engle's (1997) proposal is similar to accounts of WMC that emphasize its role in the active maintenance of task goals in attention (Conway, Cowan, & Bunting, 2001; Hasher, Lustig, & Zacks, 2008; Kane & Engle, 2000). Moreover, Unsworth and Engle (2007) have speculated that "individual differences in WMC occur not only because of differences in active maintenance, but also because of differences in the ability to use cues to guide the search process from secondary memory [i.e., long-term memory]" (p. 125). By this account, a key function of working memory is to facilitate goal maintenance; as a corollary, working memory should govern search across various task domains—and might thus represent a general executive search process.

According to the theory of an executive search process (Hills et al., 2010), the maintenance of one goal requires the ability to inhibit competing goals. As competing goals represent noise (at least in the local function of manifesting action toward the purpose of the current dominant goal), goal maintenance is analogous to discriminating signal from noise. Individuals who have difficulty suppressing the noise will, ceteris paribus, have a greater tendency to transition between representations; that is, goal maintenance and thus the ability to focus search on one local area is jeopardized by the inability to inhibit competing goals. In the case of memory search, an inability to inhibit competing search criteria should manifest itself in more frequent global transitions and, thus, shorter periods of time between local-to-global transitions. Accordingly, the time between local-to-global transitions should be positively related to WMC.

Alternatively, it is also possible that social recall is unrelated to WMC. Moscovitch (1995) noted an important distinction between strategic, or effortful, recall—which involves working memory—and routine, or automatic recall processes—which are mainly driven by frequency (or familiarity) and do not involve working memory. If search in social memory is mainly driven by frequency, we should not expect to find a relation with WMC (see also Oberauer, 2005).

## The Current Study

We examined the influence of categorical, associative, and frequency factors as well as the relationship between dynamic search in social memory and WMC by employing a social fluency task. In this task, we asked participants to recall "people that you know." To model participants' responses in the social fluency task, we additionally collected three types of information about the recalled individuals. First, we asked them to indicate each individual's social category (partner, family member, friend, or acquaintance) as well as how frequently they have contact with each recalled individual. Additionally, each participant reconstructed the connections between these individuals (i.e., whether and how well they know each other). These three types of information—social category, frequency, and social proximity—served as the input for the computational models we tested and were taken to define *retrieval structures*, from which individuals may be sampled. To test the contribution of executive attentional capacities to social recall, participants returned to the laboratory approximately 2 weeks later to take an operation span task (Unsworth, Heitz, Schrock, & Engle, 2005), which measures WMC. In the operation span task, people have to remember a sequence of letters that appear following individual math operations that must be solved (e.g., $1 \times 2 + 1 = ?$). For the purpose of reliability, at the second session, participants were also again presented with the social fluency task and again provided social-category, frequency, and social-proximity information.[2]

This approach allowed us to construct possible representations of the social memory space for each of our participants and to then model the search process for each participant. Specifically, we tested (a) the influence of categorical, associative, and frequency-based search processes, and (b) whether, as predicted by a dynamic search process, individual differences in the time period between transitions are related to working memory span.

## Method

### Participants

Thirty-six students (31 women; mean age = 22.6 years) from the University of Basel participated in the experiment. One participant with an operation span of 9, being more than one standard deviation below the next lowest participant, was removed. The average operation span of the remaining participants was 43.06 ($SD$ = 11.55), ranging between 23 and 68.

### Materials and Procedure

In the *social fluency task*, participants were seated in front of a computer and provided with instructions (in German) to type in "the names of people that you know" in such a way that they could unambiguously identify the names later. After typing in a name, the name disappeared from the screen (i.e., participants could not review the persons they had already recalled). The time interval between finishing a name and typing the first letter of the next name was recorded. Participants were not told how many names to produce, but the task terminated after 35 entries.[3] If no more individuals could be recalled before reaching 35, participants could terminate the task themselves (five participants recalled only 34 individuals, and two participants recalled 31 and 33 individuals, respectively). The social fluency task was followed by a series of further tasks that asked questions about the recalled individuals. First, participants were to indicate a social category for each individual (with categories ordered by social closeness to the participant, with lower numbers indicating greater closeness: 1 = *partner*, 2 = *family*, 3 = *friend*, 4 = *acquaintance*). Second, they were to report how frequently they encountered each individual (on a scale ranging from 1 to 5, with 1 = *about once in 6 months or less*, 2 = *several times in 6 months*, 3 = *several times a month*, 4 = *several times a week*, 5 = *daily*). Third, participants were presented with all pairwise comparisons of the recalled individuals (35 individuals yield 595 pairs) and were to indicate their social proximity, that is, how "familiar" the two individuals in each pair

[2] Individual patterns of social recall were strongly correlated between Sessions 1 and 2 (clustering coefficient, $r = .71$, $p < .001$; total time of production, $r = .54$, $p < .001$). Unless stated otherwise, for the reported results, we first averaged within an individual across both sessions. In all cases, the patterns of results were the same when taking either session individually.

[3] This number may appear small given that estimates of the size of personal networks have yielded numbers of 150 individuals and larger (e.g., Dunbar, 1993; Killworth, Johnsen, Bernard, Shelley, & McCarty, 1990). Our reason for focusing on the first 35 recalled individuals was that this number yielded a still manageable number of pairwise comparisons, which we used to collect information about the social proximity among the recalled individuals (35 individuals yield 595 pair comparisons). Moreover, note that there are several studies in which participants, given unrestricted time to retrieve people they know (without further cueing), recalled an average of about 30 (or fewer) individuals (e.g., Brewer et al., 2005; Brewer & Yang, 1994; but see Bond et al., 1985).

were with one another (on a scale ranging from 1 = *do not know each other at all* to 4 = *know each other well*). This latter information allowed us to reconstruct the structure of (a part of) each participant's personal social network (i.e., their ego network), corresponding to the recalled social contacts. Participants completed the experiment in approximately 45 min.

Participants visited the laboratory twice, separated by at least 2 weeks. During their first visit, they completed the social fluency task and answered the questions concerning the individuals recalled as described above. During their second visit, participants additionally completed an automated version of the *operation span task* presented on a computer. In this task, participants were presented with a sequence of letters (ranging from three to seven letters), which they were instructed to remember while simultaneously solving math operations. The operation span score was determined as the sum of all correctly recalled letter sets following correct math solutions. Higher scores indicate higher WMC.

## Results

Participants took a mean time of 1.64 min ($SD$ = 0.56) to complete the recall task, averaging 2.9 s ($SD$ = 1.0) per individual recalled. Table 1 shows the average percentage of recalled individuals that were classified as belonging to the different social categories as well as the distribution across the different levels of contact frequency.

What are the patterns in which participants recalled members of their personal social networks in the social fluency task? For illustration, Figure 1 provides typical production patterns of two participants as well as a representation of the networks among the individuals the two participants recalled.[4] In the networks, edges between individuals indicate individuals who knew one another (i.e., social proximity > 1). The production patterns in Figure 1 illustrate several interesting regularities. First, the participants tend to recall family and friends first, and acquaintances later. Second, social contacts belonging to the same social category seem to be retrieved clustered together (consistent with categorical recall). Third, these participants appear to recover individuals successively who know each other (i.e., social proximity > 1), as most recoveries are between individuals who share an edge in the social networks (consistent with associative recall). Fourth, individual differences in clustering may reflect differences in operation span; the upper individual has a higher operation span and appears to show more clustering both by category and social proximity. In the following, we evaluate the generality of these four patterns across all participants.

Table 1
*Average Percentage of Participants Recalled in the Social Fluency Task Who Were Classified as Belonging to the Different Social Categories and Levels of Contact Frequency, Respectively*

| Variable | % of recalled individuals |
|---|---|
| Social category | |
| Partner | 2.2 (0.78) |
| Family | 23.6 (10.97) |
| Friends | 46.0 (15.84) |
| Acquaintances | 30.2 (14.05) |
| Frequency of contact | |
| Daily | 10.19 (9.41) |
| Several times a week | 16.88 (7.70) |
| Several times a month | 23.28 (8.67) |
| Several times in 6 months | 25.88 (8.39) |
| About once in 6 months or less | 23.77 (12.97) |

*Note.* Standard deviations are in parentheses.

### Recall by Social Category, Contact Frequency, and Social Proximity

Figure 2 shows for each social category the mean rank order in which an individual was recalled as well as the mean frequency of contact. As can be seen, participants tended to retrieve social contacts in the order of partner, family, friends, and acquaintances. At the same time, participants tended to retrieve individuals encountered frequently earlier than individuals encountered less frequently. A mixed regression analysis, using each participant as a grouping variable, showed that in predicting recall order, social category and contact frequency—which were positively correlated with each other (the average correlation across participants was significantly greater than zero, $r$ = .27, $t(34)$ = 7.02, $p < .001$)—have independent effects: social category, $B$ = 3.07, $t(2324)$ = 12.11, $p < .001$; contact frequency, $B$ = –10.73, $t(2324)$ = –12.31, $p < .001$. In other words, frequently contacted people are recalled earlier, irrespective of social category, and people in close social categories are recalled earlier, irrespective of the frequency of contact with them. These independent effects support both the frequency and category accounts of social recall.

However, there is also evidence for the influence of an associative search policy. A mixed regression analysis revealed that the recovery time (in seconds) between successively recalled individuals was inversely related to how well the two individuals know each other (i.e., their social proximity), $B$ = –1.1, $t(2325)$ = –18.92, $p < .001$.

To evaluate the influence of associative and categorical search policies along a common dimension, we used a measure of clustering frequently used in the social memory literature, the adjusted ratio of clustering (ARC; Brewer et al., 2005; Roenker, Thompson, & Brown, 1971). It expresses the degree to which recall is clustered with respect to a particular set of inter-item relations (e.g., categories or social proximity). ARC is computed as the difference in the observed clustering for a given participant ($O$) and the expected clustering if recall ordering were random ($E$), relative to the difference between the maximum potential clustering ($M$) and the expected clustering (for further details, see Brewer et al., 2005):

$$ARC = \frac{O - E}{M - E}. \quad (1)$$

[4] Brewer (1993) distinguished three aspects of recall patterns in a social fluency task: (a) clustering, that is, the relationship between consecutively recalled individuals; (b) the serial order in which individuals are recalled; and (c) the frequency with which individuals are recalled. In the following, we consider both clustering and serial order to examine the contributions of contact frequency and associative and categorical search policies. Our computational model, by contrast, focuses on clustering (i.e., it predicts the probability that search moves from one recalled individual to another).

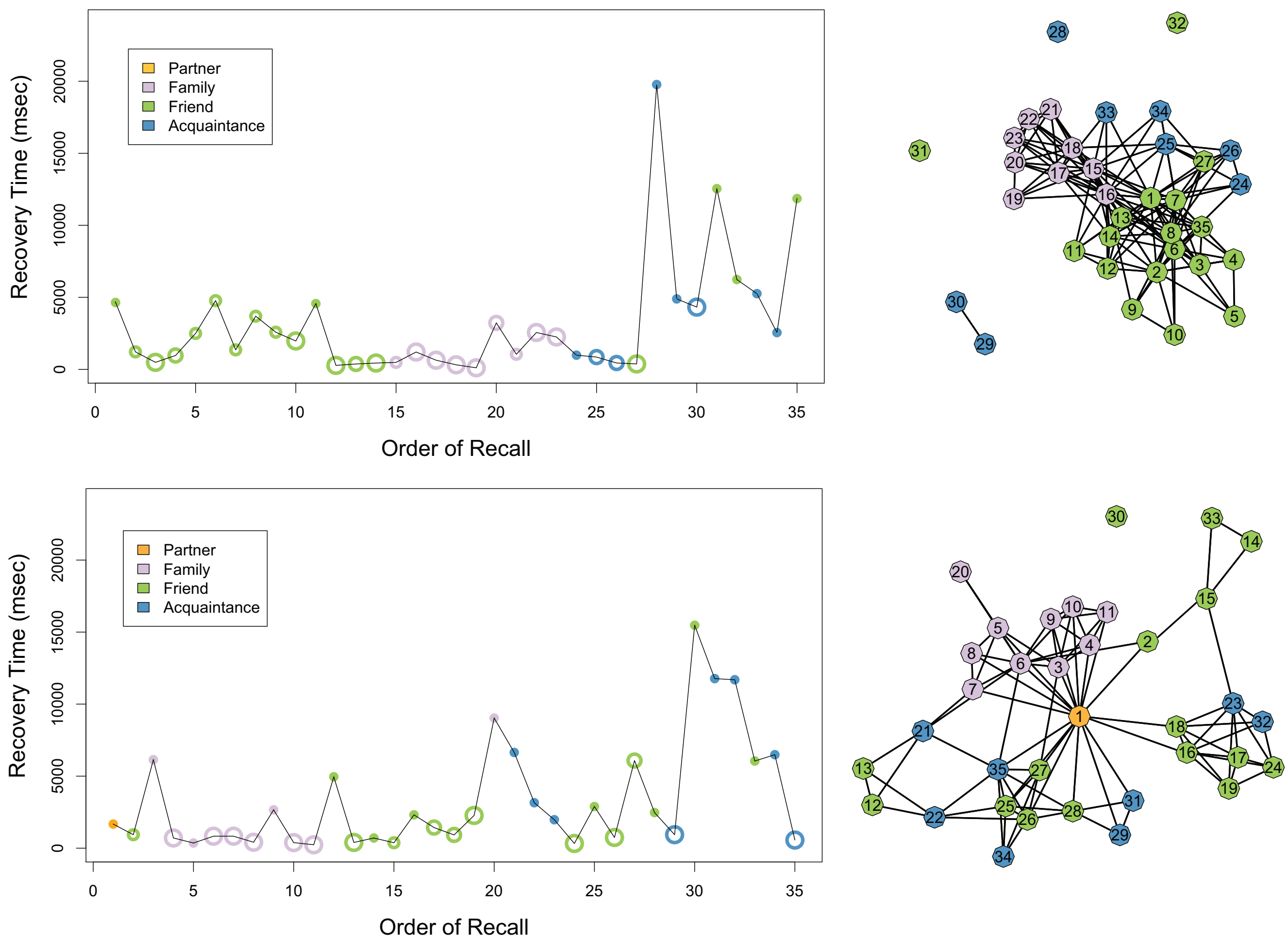


*Figure 1.* Typical retrieval patterns for two participants and their corresponding social networks. Dots represent individual recoveries. Size indicates the social proximity with the individual retrieved previously, with the smallest, closed dots having no social proximity with the prior individual, and larger dots having the highest social proximity with the prior individual. Social networks to the right correspond with the retrieval patterns on the left. Numbers inside vertices indicate the order of retrieval. The participant in the upper frame has an operation span of 44. The participant in the lower frame has an operation span of 27.

For all three parameters—*O*, *E*, and *M*—clustering is computed as the number of adjacently recalled items that are from the same category (for categorical clustering) or that have social proximity $> 1$ (for clustering according to social proximity). ARC takes on the value of 1 if a person produces the smallest possible number of switches between clusters, and 0 if clustering is at the level expected by chance.[5]

For social category, we found an average (across participants) ARC of .58 ($SD$ = .21), significantly higher than zero, $t(34) = 14.46$, $p < .001$. This value is higher than what is usually observed for social categorical recall. For instance, in Sedikides and Ostrom's (1988) meta-analysis, the average ARC was .14. This suggests that the social grouping into partner, family, friends, and acquaintances captures the influence of social categories rather well when compared with alternative grouping schemes. The average ARC for social proximity was .73 ($SD$ = .08), significantly higher than zero, $t(34) = 56.22$, $p < .001$ (one-sample *t* test), and also significantly higher than the ARC for social category, $t(34) = 4.34$, $p < .001$ (paired *t* test).

One way to disentangle the contributions of social category and social proximity, which also controls for the simultaneous influence of contact frequency, is to use formal cognitive modeling (for an alternative approach, see Brewer & Yang, 1994). In the next section, we describe a computational modeling framework of memory recall and ask which type of search process based on the above search criteria offers the most parsimonious explanation for the observed sequence in which individuals were recalled.

[5] Determining the amount of clustering expected by chance, *E*, for social proximity is computationally intensive and was solved using the graph-theoretic method described in Brewer et al. (2005).

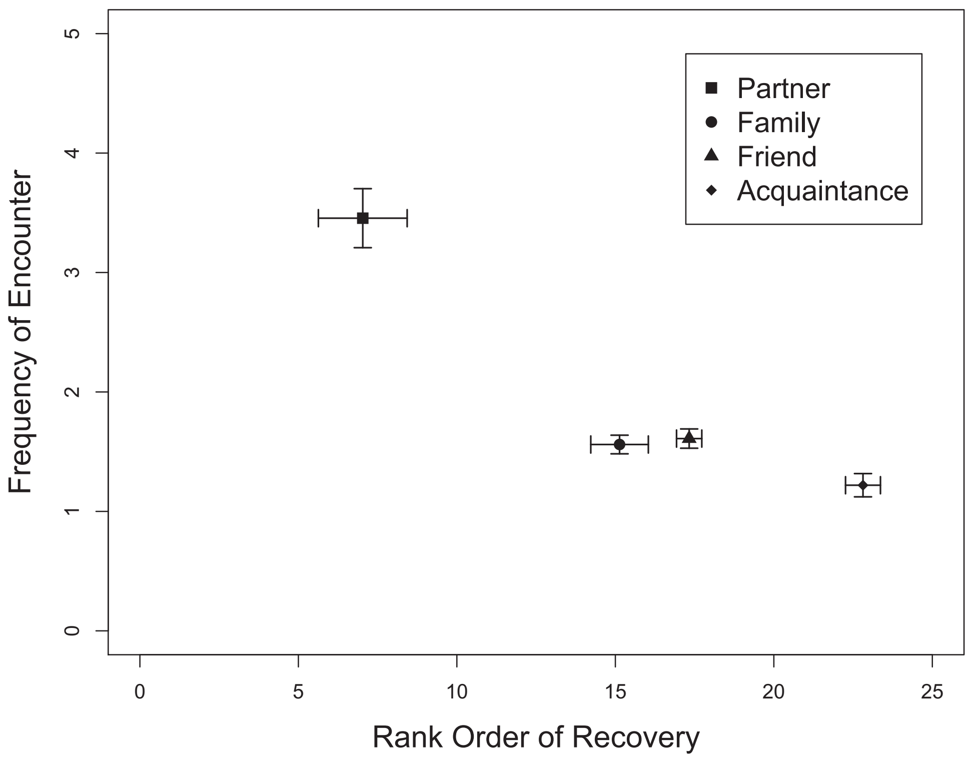


*Figure 2.* Mean rank order of recovery by frequency of encounter for each social category. Error bars represent *SEM*.

## Modeling Social Recall

To model how each participant recalled individuals, we used a modeling framework similar to the memory sampling process described by SAM (see Hills, Todd, & Jones, 2009; Raaijmakers & Shiffrin, 1981). SAM assumes that memory search is initiated by a cue (or a set of cues), $Q$, which activates a set of items (i.e., individuals), $I$, in memory in proportion to its similarity to those items, $S_k(Q, I)$, within a particular retrieval structure, $k$, of which there are $M$. Our data allowed us to describe three *retrieval structures*: one each for social category, social proximity, and frequency of contact, which are represented as matrices that describe how strongly an item in memory is activated in response to a given cue. Thus, the predicted probability that a given item, $I_i$, is sampled from memory is a function of the item's similarity to one or more cues used to probe memory divided by the similarity of all other items activated by the same cue(s) (cf. Romney, Brewer, & Batchelder, 1993):

$$P(I_i|Q_1, Q_2, \ldots, Q_M) = \frac{\prod_{k=1}^{M} S_k(Q_k, I_i)^{w_k}}{\sum_{j=1}^{N} \prod_{k=1}^{M} S_k(Q_k, I_j)^{w_k}}. \quad (2)$$

$S_k(Q_k, I_i)$ represents the retrieval strength from cue $Q_k$ to individual $I_i$ in social memory, and $w_k$ represents the *saliency* (Raaijmakers & Shiffrin, 1981) of the $k$th retrieval structure. Higher values of $w_k$ lead to a stronger influence of the cue on the predicted probability.

Here, we consider two cues, representing the global and local aspects of memory search, respectively: a context cue and a cue representing the most recently recalled individual. The context cue represents a global search cue, activating each individual in proportion to his or her global strength of activation in the overarching category of "people that you know." In line with previous work (Raaijmakers & Shiffrin, 1981), we assume that the global strength is best approximated by a retrieval structure defined by the frequency of contact with each individual. The local cue is represented by the most recently recalled individual and activates other individuals in retrieval structures defined by either social category (implementing categorical recall) or social proximity (implementing associative recall). For categorical recall, the activation strength of an individual corresponds to whether it shares the same category as the most recently recalled individual (e.g., family). For example, retrieval of a friend would preferentially activate other individuals that are also in the friends category. For associative recall, the activation strength of an individual corresponds to how well that person knows the most recently recalled individual. For example, if the most recently recalled individual was grandma, other individuals would be activated as a function of their social proximity to grandma; that is, if the participant indicates that "grandma" and "grandpa" know each other with a value of 4, then $S$("grandma," "grandpa") = 4. Thus, each of the retrieval structures (representing either frequency, social category, or social proximity) is a matrix providing the retrieval strength for each possible cue with all remaining social contacts.[6] Given a set of cues and a set of retrieval structures for each participant, we determined the best fitting saliency parameter, $w_k$, for each retrieval structure, $k$, for each participant, and we computed the predicted retrieval probability for each observed sequence of recalled individuals.

Using this framework, we tested several static and dynamic models that differed in terms of which retrieval structures guide search and how cues are used during the search process. Static models used the same combination of cues and retrieval structures over the entire production interval (e.g., always using the global context represented by frequency). Dynamic models, by contrast, transitioned between local and global cues. We defined local-to-global transitions as follows: When searching associatively, local-to-global transitions (i.e., from social proximity and frequency to frequency alone)[7] occurred whenever an individual was produced who does not know the individual recalled immediately prior to him or her (closed circles in Figure 1). When searching categorically, local-to-global transitions (i.e., from social category and frequency to frequency alone) occurred whenever two successively recalled individuals did not share the same category (changes in color in Figure 1). In a dynamic model, the probability of recall during local and global search was thus computed based on different cues (for a related example, see Gronlund & Shiffrin, 1986).

Table 2 presents for static models the median (across participants) improvement over a random model[8] in the Bayesian information criterion as well as the median $w$ and number of free parameters. Note that the static and dynamic models are not strictly comparable, as to identify transition points, the dynamic models used information from the data about the to-be-retrieved items. We turn to the question of whether the data are better accounted for by a static or dynamic process in the next section.

Table 2
*Median Improvement in the Bayesian Information Criterion (BIC) Relative to a Random Model for Static Recall Models That Use One or More Cues*

| Retrieval structure | BIC improvement (*Mdn*) | $w$ (*Mdn*) | No. of free parameters |
|---|---|---|---|
| | Single-cue models | | |
| Frequency | 32.30 | 1.01 | 1 |
| Shared category | 35.85 | 2.38 | 1 |
| Social proximity | 51.24 | 2.81 | 1 |
| | Multi-cue model | | |
| Frequency+ | 32.28 | 3.28 | 2 |
| Category | | 2.38 | |
| Frequency+ | 47.68 | 2.54 | 2 |
| Social proximity | | 2.81 | |
| Social proximity+ | 49.93 | 2.57 | 2 |
| Category | | 1.32 | |
| Frequency+ | 44.13 | 3.74 | 3 |
| Social proximity+ | | 2.38 | |
| Category | | 1.37 | |

*Note.* Models were fit using the maximum likelihood method to find the optimal $w$ (medians reported) for each cue-retrieval structure combination for each individual. A plus sign indicates that the product of the retrieval strengths was computed in Equation 2 for the local memory search.

The results in Table 2 indicate that among the static models, the one that assumes that recall follows social proximity captures the data best. This is consistent with the ARC results from above. Although our approach also allows us to test static models that are based on multiple cues in combination, all of these models performed worse than the model using social proximity alone.

With regard to the dynamic models, the results indicate that the model that assumes a global structure defined by frequency and a local structure defined by social proximity and frequency captures the data best (see Table 3). Models assuming a local structure defined by social category, either alone or in combination with social proximity, performed worse. For all models, the $w$ parameters were positive. In summary, both static and dynamic model comparisons converge on supporting a search process in which social proximity plays a key role, whereas social categories do not. Next, we examine whether, as predicted by a dynamic (but not by a static) mechanism, the time period between transitions from local to global search criteria was correlated with WMC.

## Working Memory and Local-to-Global Transitions

Is there evidence that recall from social memory is governed by a dynamic local-to-global search policy? As described above, a domain-general executive search process predicts that for people with a high operation span, the time period between transitions from local to global search criteria is longer than for people with a low operation span. The reason is that low-span people should have a reduced ability to maintain cues that guide local search. To test this hypothesis, we examined the relationship between the individual differences in the time period between transitions and the operation span score. Transitions were defined as alternations between local and global cues as assumed in the best performing dynamic model, that is, between social proximity and frequency. Keeping in mind the moderate sample size of participants, regressing time between transitions (i.e., switches) on operation span indeed revealed a significant relationship, $B = 117.6$, $t(34) = 2.18$, $p = .037$, $r = .35$ (see Figure 3A). In other words, participants with higher operation spans produced longer intervals of individuals who know each other than did participants with lower spans.

Importantly, the effect of working memory on the length of the time period between transitions was not due to high- and low-span participants having different network structures. As shown in Figure 3B, there was no association between operation span and clustering coefficient (which is a measure of the probability that, if

[6] SAM, as proposed by Raaijmakers and Shiffrin (1981), uses sampling-with-replacement but also includes other assumptions to eliminate repetitions during recall. As none of our participants produced repetitions, and we are not simulating productions with additional assumptions to inhibit repetitions (but assign probabilities to each item produced), we use the more appropriate sampling-without-replacement. However, none of the conclusions we make here hinges on this assumption: The qualitative patterns of results are identical to those produced by a model with replacement.

[7] This implementation is consistent with SAM (Raaijmakers & Shiffrin, 1981), which uses a local cue set that combines global and local information.

[8] The random model assumes that all remaining items in the social network have an equal chance to be recalled.

Table 3
*Median Improvement in the Bayesian Information Criterion (BIC) Compared With the Random Model for Dynamic Recall Models Incorporating Different Global and Local Representations, and Different Switching Criteria (Associative or Categorical)*

| | Switching criterion | | | | |
|---|---|---|---|---|---|
| | Associative | | Categorical | | |
| Local retrieval structure[a] | *w* (*Mdn*) | BIC improvement (*Mdn*) | *w* (*Mdn*) | BIC improvement (*Mdn*) | No. of free parameters |
| Frequency+ | 4.89 | 52.93 | 3.43 | 41.21 | 2 |
| Social proximity | 2.76 | | 3.19 | | |
| Frequency+ | 3.30 | 29.51 | 3.69 | 41.75 | 2 |
| Social category | 3.50 | | 52.15 | | |
| Frequency+ | 4.43 | 49.29 | 2.44 | 45.92 | 3 |
| Social proximity+ | 1.81 | | 2.79 | | |
| Social category | 1.67 | | 31.78 | | |

*Note.* A plus sign indicates the product of the retrieval strengths computed according to Equation 2 for the local memory search.
[a] In all models, frequency was used as the global retrieval structure.

an individual knows two other individuals in a network, those two individuals also know one another; $r = -.04$, $p = .82$). Moreover, operation span was unrelated to network density. We quantified network density for each participant as the number of connections between recalled individuals (defined as social proximity $> 1$) in the participant's ego network, relative to the maximal number of connections possible. The correlation between network density and operation span was not significant ($r = -.28$, $p > .1$). The lack of associations between operation span and network characteristics indicates that the observed differences in recall patterns between high- and low-span participants are mainly driven by the executive control of memory and not by the idiosyncratic structure of their ego networks. Finally, participants with high and low operation spans did not differ with regard to the mean time spent to recall each individual ($r = .10$, $p = .55$; see Figure 3C).

## Discussion

Memories of our social relations offer us a rich source of information about the world (Pachur et al., in press). Previous research has indicated that social memory is structured by factors such as social categories and social proximity (e.g., Brewer, 1995; Fiske, 1995). However, despite considerable developments of computational accounts for semantic memory, there have been very few analyses of social memory using cognitive modeling. In addition, whereas research in semantic memory found evidence for a dynamic retrieval process (e.g., Raaijmakers & Shiffrin, 1981), static and dynamic search policies have not been compared in previous research on social recall. In this article, we examined the relative contribution of the potential factors underlying social recall using a cognitive modeling framework developed for semantic memory. In line with previous results, social recall was clustered in terms of social categories (e.g., Fiske, 1995) and frequency (e.g., Brewer, 1995). Nevertheless, the best static account for the data assumed recall from retrieval structures based on associative relations (i.e., social proximity), supporting the conclusions in Brewer et al. (2005). Extending Brewer et al.'s findings, we showed that a dynamic model based on associative relations and frequency fit the data still better than the static model

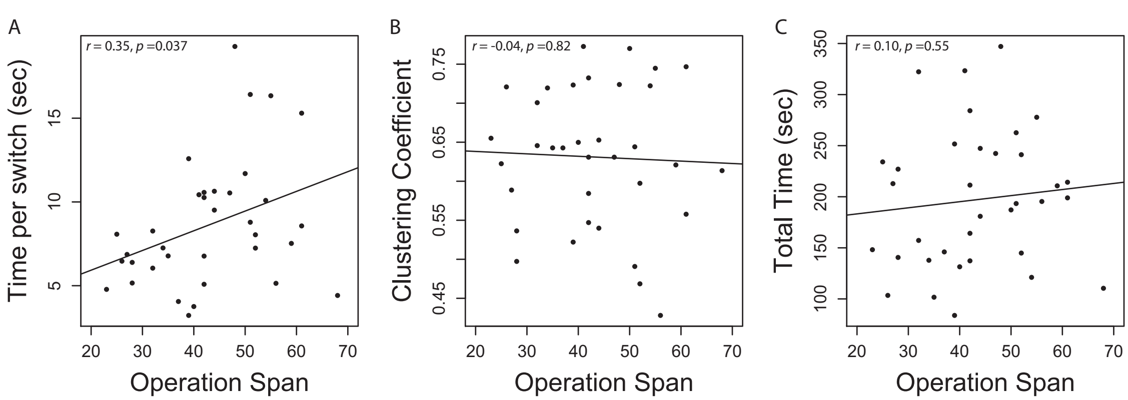


*Figure 3.* Individual data for time per switch, clustering coefficient, and total time, as a function of operation span.

and, further, that the length of the time period between dynamic local-to-global transitions in the search process correlated with a measure of executive function, namely, WMC.

These findings are consistent with the proposal that working memory span is related to goal maintenance and the effective use of local cues during retrieval from long-term memory (see Rosen & Engle, 1997; Unsworth & Engle, 2007; Unsworth, Spillers, & Brewer, 2011). Moreover, the findings presented here, along with those found between WMC and dynamic search in other domains (e.g., Rakow, Demes, & Newell, 2008), support the thesis that executive processes may act as a domain-general search process, controlling goal abandonment in both external and internal domains (Hills et al., 2010, 2009).

An important aspect of our approach is that it allows a definition of clusters based on participant's own idiosyncratic search environments—as opposed to analyses based on hand-coded categorizations (e.g., Troyer et al., 1998) or randomly generated search environments (e.g., Harbison, Dougherty, Davelaar, & Fayyad, 2009; Raaijmakers & Shiffrin, 1981). Because this approach makes explicit the putative internal representational environments over which participants may search, it allows us to compete alternative (categorical, associative, and frequency) representations against one another and, thus, to further infer the structure of individual memory representations. More general but less idiosyncratic representations of memory domains have been constructed to represent memory, for example, by using semantic space models, which capture semantic relations between words in natural text (e.g., Jones & Mewhort, 2007), or feature norms that allow objects to be associated based on shared features (e.g., feature norms; McRae, Cree, Seidenberg, & McNorgan, 2005). As here, such representations offer a powerful tool for future investigations of cognitive search processes and the representations over which they search.

Our results have implications for categorical versus associative accounts of long-term memory retrieval. In particular, they support previous findings indicating that social memory is based on associative relations between items in memory (Brewer et al., 2005), *not* on first identifying categories (e.g., family), and then identifying items with a category. This finding contrasts with some findings for semantic memory. Notably, much research has found support for categorical clustering using the hand-coded categories of Troyer et al. (1998; also see Lanting, Haugrud, & Crossley, 2009; Troyer, 2000). However, recent research on semantic memory has shown that recall patterns can appear to be categorical even when the underlying processes are more consistent with associative search policies (Hills et al., 2009). Whether the existing evidence for categorical search in semantic search is real or apparent is an important question for future research—as is the question of why the prevalence of different search policies might differ between social and semantic search (or even between individuals). Importantly, such insights into the structure of memory may be quite useful in improving recall, as has been shown by Pollio and Gerow (1968).

A second issue on which the present approach may be helpful refers to the factors underlying cognitive stopping rules in memory search. One prominent proposal is that people stop search when the number of retrieval failures reaches a certain threshold (Harbison et al., 2009; see also Dougherty & Harbison, 2007). Work on individual differences (e.g., Unsworth et al., 2011) and the work presented here indicate that additional factors may be at play, including the ability of individuals to use and maintain local cues during memory search. On the other hand, individual differences in cue maintenance might also be related to differences in the retrieval failure thresholds for determining when to abandon search. Relatedly, it is important to investigate "where" in a retrieval structure stopping is most likely to take place (for an attempt in this direction, see Hills et al., 2009).

Finally, the present research offers insights into how social memory might shape our inferences about the world. Traditionally, memory-based decision making has been suggested to mainly depend on the frequency and "availability" of traces in social memory (e.g., Tversky & Kahneman, 1973). Our results, by contrast, hint that search is not generally driven by a static and automatic process guided by frequency (Moscovitch, 1995). Rather, search seems to involve, in addition to an automatic process based on frequency, a strategic component based on inter-item associations—especially among people with high working span. It is likely that these relations also influence how our social memories shape our views of world.

## References

Anderson, J. R. (1993). *Rules of the mind.* Hillsdale, NJ: Erlbaum.

Anderson, J. R., & Schooler, L. J. (1991). Reflections of the environment in memory. *Psychological Science, 2,* 396–408. doi:10.1111/j.1467-9280.1991.tb00174.x

Bahrick, H. O., Bahrick, P. C., & Wittlinger, R. P. (1975). Fifty years of memories for names and faces: A cross-sectional approach. *Journal of Experimental Psychology: General, 104,* 54–75. doi:10.1037/0096-3445.104.1.54

Bond, C. F., Jr., & Brockett, D. R. (1987). A social context-personality index theory of memory of acquaintances. *Journal of Personality and Social Psychology, 52,* 1110–1121. doi:10.1037/0022-3514.52.6.1110

Bond, C. F., Jr., Jones, R. L., & Weintraub, D. L. (1985). On the unconstrained recall of acquaintances: A sampling-traversal model. *Journal of Personality and Social Psychology, 49,* 327–337. doi:10.1037/0022-3514.49.2.327

Bousfield, W. A., & Sedgewick, C. H. (1944). An analysis of restricted associative responses. *Journal of General Psychology, 30,* 149–165.

Boyce, C. J., Brown, G. D. A., & Moore, S. C. (2010). Money and happiness: Rank of income, not income, affects life satisfaction. *Psychological Science, 21,* 471–475. doi:10.1177/0956797610362671

Brewer, D. D. (1993). Patterns in the recall of persons in a student community. *Social Networks, 15,* 335–359. doi:10.1016/0378-8733(93)90011-9

Brewer, D. D. (1995). The social structural basis of the organization of persons in memory. *Human Nature, 6,* 379–403. doi:10.1007/BF02734207

Brewer, D. D., & Garrett, S. B. (2001). Evaluation of interviewing techniques to enhance recall of sexual and drug injection partners. *Sexually Transmitted Diseases, 28,* 666–677. doi:10.1097/00007435-200111000-00010

Brewer, D. D., Garrett, S. B., & Rinaldi, G. (2002). Free listed items are effective cues for eliciting additional items in semantic domains. *Applied Cognitive Psychology, 16,* 343–358. doi:10.1002/acp.797

Brewer, D. D., Rinaldi, G., Mogoutov, A., & Valente, T. W. (2005). A quantitative review of associative patterns in the recall of persons. *Journal of Social Structure, 6*(1).

Brewer, D. D., & Yang, B. L. (1994). Patterns in the recall of persons in a religious community. *Social Networks, 16,* 347–379. doi:10.1016/0378-8733(94)90016-7

Brown, G. D. A., Gardner, J., Oswald, A. J., & Qian, J. (2008). Does wage rank affect employees' well-being? *Industrial Relations: A Journal of Economy and Society, 47,* 355–389.

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8,* 331–335. doi:10.3758/BF03196169

Dougherty, M. R., & Harbison, J. I. (2007). Motivated to retrieve: How often are you willing to go back to the well when the well is dry? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 1108–1117. doi:10.1037/0278-7393.33.6.1108

Dunbar, R. I. M. (1993). Coevolution of neocortical size, group size and language in humans. *Behavioral and Brain Sciences, 16,* 681–694. doi:10.1017/S0140525X00032325

Fiske, A. P. (1995). Social schemata for remembering people: Relationships and person attributes in free recall of acquaintances. *Journal of Quantitative Anthropology, 5,* 305–324.

Gronlund, S. D., & Shiffrin, R. M. (1986). Retrieval strategies in recall of natural categories and categorized lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 550–561. doi:10.1037/0278-7393.12.4.550

Gruenewald, P. J., & Lockhead, G. R. (1980). The free recall of category examples. *Journal of Experimental Psychology: Human, Learning, and Memory, 6,* 225–240. doi:10.1037/0278-7393.6.3.225

Harbison, J. I., Dougherty, M. R., Davelaar, E. J., & Fayyad, B. (2009). On the lawfulness of the decision to terminate memory search. *Cognition, 111,* 397–402. doi:10.1016/j.cognition.2009.03.002

Hasher, L., Lustig, C., & Zacks, R. (2008). Inhibitory mechanisms and the control of attention. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake, & J. N. Towse (Eds.), *Variation in working memory* (pp. 227–249). New York, NY: Oxford University Press.

Hertwig, R., Pachur, T., & Kurzenhäuser, S. (2005). Judgments of risk frequencies: Tests of possible cognitive mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 621–642. doi:10.1037/0278-7393.31.4.621

Hills, T. T., Todd, P. M., & Goldstone, R. G. (2008). Search in external and internal spaces: Evidence for generalized cognitive search processes. *Psychological Science, 19,* 676–682. doi:10.1111/j.1467-9280.2008.02160.x

Hills, T. T., Todd, P. M., & Goldstone, R. G. (2010). The central executive as a search process: Priming exploration and exploitation across domains. *Journal of Experimental Psychology: General, 139,* 590–609. doi:10.1037/a0020666

Hills, T., Todd, P. M., & Jones, M. (2009). Optimal foraging in semantic memory. In N. A. Taatgen & H. van Rijn (Eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society* (pp. 620–625). Austin, TX: Cognitive Science Society.

Jones, M. N., & Mewhort, D. J. K. (2007). Representing word meaning and order information in a composite holographic lexicon. *Psychological Review, 114,* 1–37. doi:10.1037/0033-295X.114.1.1

Kane, M. J., & Engle, R. W. (2000). Working memory capacity, proactive interference, and divided attention: Limits on long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, Cognition, 26,* 333–358. doi:10.1037/0278-7393.26.2.336

Killworth, P. D., Johnsen, E. C., Bernard, H. R., Shelley, G. A., & McCarty, C. (1990). Estimating the size of personal networks. *Social Networks, 12,* 289–312. doi:10.1016/0378-8733(90)90012-X

Klein, S. B., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological Review, 109,* 306–329. doi:10.1037/0033-295X.109.2.306

Kleinberg, J. (2000, August 24). Navigation in a small world. *Nature, 406,* 845. doi:10.1038/35022643

Lanting, S., Haugrud, N., & Crossley, M. (2009). The effects of age and sex on clustering and switching during speeded verbal fluency tasks. *Journal of the International Neuropsychological Society, 15,* 196–204. doi:10.1017/S1355617709090237

McRae, K., Cree, G. S., Seidenberg, M. S., & McNorgan, C. (2005). Semantic feature production norms for a large set of living and nonliving things. *Behavior Research Methods, 37,* 547–559. doi:10.3758/BF03192726

Milgram, S. (1967). The small world problem. *Psychology Today, 2,* 60–67.

Moscovitch, M. (1995). Models of consciousness and memory. In M. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1341–1356). Cambridge, MA: MIT Press.

Murray, W. S., & Forster, K. I. (2004). Serial mechanisms in lexical access: The rank hypothesis. *Psychological Review, 111,* 721–756. doi:10.1037/0033-295X.111.3.721

Oberauer, K. (2005). Binding and inhibition in working memory: Individual and age differences in short-term recognition. *Journal of Experimental Psychology: General, 134,* 368–387. doi:10.1037/0096-3445.134.3.368

Pachur, T., Hertwig, R., & Rieskamp, J. (in press). The mind as an intuitive pollster: Frugal search in social spaces. In R. Hertwig, U. Hoffrage, & the ABC Research Group (Eds.), *Simple heuristics in a social world.* New York, NY: Oxford University Press.

Pollio, H. R., & Gerow, J. R. (1968). The role of rules in recall. *American Journal of Psychology, 81,* 303–313. doi:10.2307/1420627

Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review, 88,* 93–134. doi:10.1037/0033-295X.88.2.93

Rakow, T., Demes, K. A., & Newell, B. R. (2008). Biased samples not mode of presentation: Re-examining the apparent underweighting of rare events in experience-based choice. *Organizational Behavior and Human Decision Processes, 106,* 168–179. doi:10.1016/j.obhdp.2008.02.001

Roenker, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin, 1,* 45–48. doi:10.1037/h0031355

Romney, A. K., Brewer, D. D., & Batchelder, W. H. (1993). Predicting clustering from semantic structure. *Psychological Science, 4,* 28–34. doi:10.1111/j.1467-9280.1993.tb00552.x

Rosen, V. M., & Engle, R. W. (1997). The role of working memory capacity in retrieval. *Journal of Experimental Psychology: General, 126,* 211–227. doi:10.1037/0096-3445.126.3.211

Sedikides, C., & Ostrom, T. (1988). Are person categories used when organizing information about unfamiliar sets of persons? *Social Cognition, 6,* 252–267. doi:10.1521/soco.1988.6.3.252

Stevens, J. R., & Hauser, M. D. (2004). Why be nice? Psychological constraints on the evolution of cooperation. *Trends in Cognitive Sciences, 8,* 60–65. doi:10.1016/j.tics.2003.12.003

Troyer, A. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology, 22,* 370–378. doi:10.1076/1380-3395(200006)22:3;1-V;FT370

Troyer, A. K., Moscovitch, M., Winocur, G., Alexander, M. P., & Stuss, D. (1998). Clustering and switching on verbal fluency: The effects of focal frontal- and temporal-lobe lesions. *Neuropsychologia, 36,* 499–504. doi:10.1016/S0028-3932(97)00152-8

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53,* 1–25. doi:10.1146/annurev.psych.53.100901.135114

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5,* 207–232. doi:10.1016/0010-0285(73)90033-9

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114,* 104–132. doi:10.1037/0033-295X.114.1.104

Unsworth, N., Heitz, R. C., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods, 37,* 498–505. doi:10.3758/BF03192720

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2011). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *The Quarterly Journal of Experimental Psychology, 64,* 447–466. doi:10.1080/17470218.2010.505292

Williams, M. D., & Hollan, J. D. (1981). The process of retrieval from very long-term memory. *Cognitive Science, 5,* 87–119. doi:10.1207/s15516709cog0502_1

Received April 27, 2011
Revision received July 1, 2011
Accepted July 11, 2011 ■

UNITED STATES POSTAL SERVICE®

**Statement of Ownership, Management, and Circulation (All Periodicals Publications Except Requester Publications)**

1. Publication Title: Journal of Experimental Psychology: Learning, Memory and Cognition
2. Publication Number: 0 8 6 - 5 7 0
3. Filing Date: October 2011
4. Issue Frequency: Bimonthly
5. Number of Issues Published Annually: 6
6. Annual Subscription Price: Mbr $167 Indiv $392 Inst $1148
7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4®): 750 First Street, NE, Washington, DC 20002-4242
Contact Person: Barbara Spruill
Telephone (Include area code): 202 336-5578
8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer): 750 First Street, NE, Washington, DC 20002-4242
9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Do not leave blank)

Publisher (Name and complete mailing address)
American Psychological Association
750 First Street, NE
Washington, DC 20002-4242

Editor (Name and complete mailing address)
Randi C. Martin, PhD., Department of Psychology, MS-25
Rice University, P.O. Box 1892
Houston, TX 77251

Managing Editor (Name and complete mailing address)
Susan J.A. Harris
American Psychological Association
750 First Street, NE, Washington, DC 20002-4242

10. Owner (Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)

| Full Name | Complete Mailing Address |
|---|---|
| American Psychological Association | 750 First Street, NE |
| | Washington, DC 20002-4242 |

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. If none, check box ☒ None

| Full Name | Complete Mailing Address |
|---|---|
| None | |

12. Tax Status (For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
☒ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months (Publisher must submit explanation of change with this statement)

PS Form 3526, September 2007 (Page 1 of 3 (Instructions Page 3)) PSN 7530-01-000-9931 PRIVACY NOTICE: See our privacy policy on www.usps.com

13. Publication Title: Journal of Experimental Psychology: Learning, Memory, and Cognition
14. Issue Date for Circulation Data Below: September 2011

| 15. Extent and Nature of Circulation | | | Average No. Copies Each issue During Preceding 12 Months | No. Copies of Single Issue Published Nearest to Filing Date |
|---|---|---|---|---|
| a. Total Number of Copies (Net press run) | | | | |
| b. Paid Circulation (By Mail and Outside the Mail) | (1) | Mailed Outside-County Paid Subscriptions Stated on PS Form 3541(Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies) | 1127 | 1100 |
| | (2) | Mailed In-County Paid Subscriptions Stated on PS Form 3541 (Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies) | 612 | 614 |
| | (3) | Paid Distribution Outside the Mails Including Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid Distribution Outside USPS® | 227 | 222 |
| | (4) | Paid Distribution by Other Classes of Mail Through the USPS (e.g. First-Class Mail®) | | |
| c. Total Paid Distribution (Sum of 15b (1), (2), (3), and (4)) | | | 839 | 836 |
| d. Free or Nominal Rate Distribution (By Mail and Outside the Mail) | (1) | Free or Nominal Rate Outside-County Copies included on PS Form 3541 | | |
| | (2) | Free or Nominal Rate In-County Copies Included on PS Form 3541 | | |
| | (3) | Free or Nominal Rate Copies Mailed at Other Classes Through the USPS (e.g. First-Class Mail) | | |
| | (4) | Free or Nominal Rate Distribution Outside the Mail (Carriers or other means) | 17 | 16 |
| e. Total Free or Nominal Rate Distribution (Sum of 15d (1), (2), (3) and (4)) | | | 17 | 16 |
| f. Total Distribution (Sum of 15c and 15e) | | | 856 | 852 |
| g. Copies not Distributed (See Instructions to Publishers #4 (page #3)) | | | 271 | 248 |
| h. Total (Sum of 15f and g) | | | 1127 | 1100 |
| i. Percent Paid (15c divided by 15f times 100) | | | 98% | 98% |

16. Publication of Statement of Ownership
☒ If the publication is a general publication, publication of this statement is required. Will be printed in the January 2012 issue of this publication. ☐ Publication not required.

17. Signature and Title of Editor, Publisher, Business Manager, or Owner: Barbara Spruill
Dir. Service Center Operations
Date: 10/11/11

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form 3526, September 2007 (Page 2 of 3)