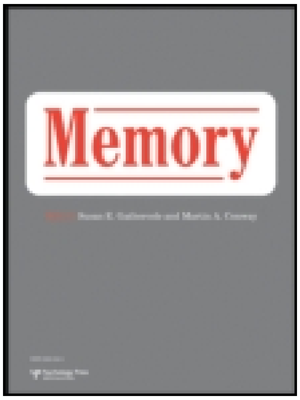

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The role of working memory capacity in autobiographical retrieval: Individual differences in strategic search

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The role of working memory capacity in autobiographical retrieval: Individual differences in strategic search

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Remembering previous experiences from one's personal past is a principal component of psychological well-being, personality, sense of self, decision making, and planning for the future. In the current study the ability to search for autobiographical information in memory was examined by having college students recall their Facebook friends. Individual differences in working memory capacity manifested itself in the search of autobiographical memory by way of the total number of friends remembered, the number of clusters of friends, size of clusters, and the speed with which participants could output their friends' names. Although working memory capacity was related to the ability to search autobiographical memory, participants did not differ in the manner in which they approached the search and used contextual cues to help query their memories. These results corroborate recent theorising, which suggests that working memory is a necessary component of self-generating contextual cues to strategically search memory for autobiographical information.

Keywords: Working memory; Autobiographical memory; Individual differences.

The ability to access information from one's personal past is of fundamental importance to aspects of personality, the self, as well as many real-world activities. For instance, simple questions such as ''Who was your favourite teacher growing up?'' and ''What did you do for your eighth birthday?'' require one to actively search autobiographical memory to come up with the appropriate answer. That is, one would need to search their autobiographical knowledge base to accurately remember the answers to these questions (Conway, 1992). Understanding how individuals retrieve information from autobiographical memory, what processes are important for effective retrieval, and whether individuals differ in their ability to retrieve from autobiographical memory is an important topic of research given how fundamental autobiographical memory is to our everyday functioning.

A number of researchers have suggested that retrieval from autobiographical memory can occur in one of two general ways (Burgess & Shallice, 1996; Conway & Pleydell-Pearce, 2000; Reiser, Black, & Abelson, 1985; Williams & Hollan, 1981). On the one hand, potent external information in terms of a retrieval cue or the question itself can directly access information stored in autobiographical memory. In such cases individuals have direct access to the sought after information, and little, if any, effort is required. On the other hand, the retrieval question and/or retrieval cues might be ill specified and not

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adequately access the desired information. In such cases individuals will have to rely on strategic search processes to attempt to access the desired information amongst other related, but irrelevant information. Such retrieval attempts require a great deal of control and effort in order to generate the correct answer.

In terms of this latter type of retrieval a number of general models have been proposed which suggest that strategic retrieval is a cyclical search process that starts with the specification of a context (i.e., cue elaboration) with which the desired information may be associated, information is then retrieved from the context, and any retrieved information is subjected to a monitoring/verification process (Burgess & Shallice, 1996; Conway & Pleydell-Pearce, 2000; Norman & Bobrow, 1979; Reiser et al., 1985; Whitten & Leonard, 1981; Williams & Hollan, 1981). If the retrieved information is considered to be accurate, that information can then be used to further specify the search and access additional information. For instance, in Reiser et al.'s (1985) context-plus-index model it is assumed that when searching autobiographical memory individuals first use strategies to generate an appropriate context for search and then search and select particular information that is indexed within that context. Likewise, in Williams and Hollan's (1981) model it is assumed that individuals first find a context, then search that context, and finally verify whether the retrieved information is correct. Similarly in the self-memory-system model of Conway and Pleydell-Pearce (2000) it is assumed that when searching the autobiographical knowledge base, one first sets up cues during the cue elaboration phase, then these cues are used to search the autobiographical knowledge base, and the products of search are checked against various verification criteria. Importantly in this model it is assume that cue elaboration and verification are control processes whereas the actual search of the autobiographical knowledge base is relatively automatic (see also Shiffrin, 1970). Overall, these general models suggest that an important component to searching autobiographical memory is the ability to generate contexts that match the retrieval question and adequately focus the search on the desired information, and the ability to use the products of the search to further specify the search and access additional information.

For instance, in these models if asked ''What did you do for your eighth birthday?'' one would use the initial question to try and specify a particular context (e.g., ''my birthdays'') and then attempt to access information relevant to a particular birthday (i.e., ''my eighth birthday''). If information is not recalled directly then the individual would have to try and further specify the context by using additional relevant information such as the fact that one would have been in the second grade on their eighth birthday. Thus the combination of a general context (birthdays), along with particular temporal information (eight years old), as well as additional relevant information (second grade) may be enough to focus the search on the desired information. That is, one could recall that on their eighth birthday they were hit in the head with a baseball bat (and subsequently fell in a swimming pool) by a party guest who was attempting to break open a piñata.[1]

Important evidence consistent with these strategic search models of autobiographical memory comes from a number of studies that have examined naturalistic recall with various think-aloud procedures (Reiser et al., 1985; Whitten & Leonard, 1981; Williams & Hollan, 1981). In the Williams and Hollan (1981) study participants were required to recall (over extended time periods) the names of individuals who were their high school classmates. While recalling, participants were instructed to think aloud and provide information on how names were being recalled. These verbal protocols were then examined to better understand the retrieval process. Williams and Hollan found that recall of names was a negatively accelerating function such individuals recalled many names early in the recall period and fewer and fewer names as recall progressed. Furthermore, based on the verbal protocols, Williams and Hollan found good evidence that participants were generating particular contexts and then searching within those contexts to recall individual names. Specifically, participants utilised various strategies (activities, locations, pictures, etc.) to find different contexts (PE classes, dances) and then searched within those contexts to find different names. For example, participants might decide to think about dances they attended and recall the names of people they took as dates to those dances. Furthermore, while recalling these names additional names might be accessed based on shared contextual information (the names of friends who attended the same dance and the

[1] This is an actual account of one of the authors' eighth birthday.

name of the friends' dates). Thus participants search for different contexts to aid in the search and then use the products of the search to find additional names that are associated with that context. Similar to search through semantic memory (Bousfield & Sedgewick, 1944) this leads to the recall of clusters of related items. For instance, in Williams and Hollan's study, participants might generate the context of classes and then recall names associated with sub-contexts such as maths class, history, English, etc. Thus participants search by first generating overarching contexts to search and then search within those contexts leading to clusters of related items.

Evidence consistent with the notion that participants generate different contexts to search leading to clusters of similar items comes from a number of studies that have found that, when participants are asked to recall people they know, they tend to generate different clusters of items and these clusters are primarily based on various social contexts. For example, Bahrick, Bahrick, and Wittlinger (1975) found that the strongest determinant of recall performance when participants were asked to recall high school classmates was social context. In particular, Bahrick et al. found that close friends and romantic relationships were the two most prominent contexts used by participants to generate names, but that participants also used shared classes and shared extra-curricular activities as contexts to search. Similar results were found by Bond and Brockett (1987) who found a large degree of clustering based on social context. Furthermore, a fine-grained examination of the clusters suggested that global clusters were based on social contexts, but there was a significant amount of sub-clustering based on personality characteristics. That is, although participants generated names based on overall social contexts (e.g., school), they also tended to cluster participants within the overall cluster based on personality traits (e.g., caring). Thus this research suggest that during the cue elaboration phase, participants are likely generating different contexts (particularly social contexts; for a review see Brewer, Rinaldi, Moguoutov, & Valente, 2005) to search and then searching within those contexts to generate information from autobiographical memory.

Theoretically these strategic search processes are reliant on intact frontally mediated control processes such as the central executive in working memory or the supervisory attentional system (Baddeley & Wilson, 1986; Burgess & Shallice, 1996; Conway, 1992; Conway & Pleydell-Pearce, 2000). Specifically it has been suggested that control is needed to generate appropriate contexts to search, to elaborate on cues needed for search, to verify the products of the search, and to adequately use the products of the search to better focus the retrieval specification (Conway, 1992; see also Shiffrin, 1970). Thus working memory control processes should be of vital importance when one is attempting to strategically search autobiographical memory, and these working memory control processes should be especially important during the cue elaboration phase where one must self-generate different contexts to search.

Recent work has suggested that working memory capacity (WMC) and individual differences in WMC (as measured by complex span tasks) is needed for retrieval from long-term memory in terms of both semantic (Rosen & Engle, 1997) and episodic recall (Unsworth, 2007). In this work it is suggested that WMC is needed for strategic search processes similar to those needed in autobiographical recall (Unsworth & Engle, 2007). For instance, Rosen and Engle (1997) found that high- and low-WMC individuals differed in their ability to retrieve animal names from semantic memory. Specifically, high-WMC individuals recalled more animal names, recalled more semantically related clusters of animal names, had larger cluster sizes, and recalled at a faster rate than low-WMC individuals. Rosen and Engle suggested that high-WMC individuals were better at self-generating cues to access animal names than low-WMC individuals leading to better overall performance. Likewise, Unsworth (2007) found that high-WMC individuals were better than low-WMC individuals at recalling words from episodic memory, recalled fewer errors, and recalled at a faster rate than low-WMC individuals. Unsworth suggested that high-WMC individuals were better at generating temporal-contextual cues to focus the search on relevant items than low-WMC individuals leading to better overall performance. Collectively these results suggest that high-WMC individuals are better at strategically searching their memory systems than low-WMC individuals, because high-WMC individuals are better at self-generating cues that specify the correct target items (Unsworth & Engle, 2007).

If this line of reasoning is correct and high-WMC individuals are better at self-generating retrieval cues (regardless of the type of memory being accessed) than low-WMC individuals, then high-WMC individuals should be better at strategically searching autobiographical memory than low-WMC individuals. That is, if strategic search of autobiographical memory is reliant on working memory control processes, then we should see that individuals who have deficits in these control processes should be less able to search their autobiographical memory systems compared to individuals who do not have such deficits. In particular, based on the prior review, high-WMC individuals should be better suited at generating and elaborating cues to generate contexts (recalling more clusters) and use the products of the search (leading to larger cluster sizes) to access autobiographical memories than low-WMC individuals. These results would provide direct evidence for the notion that WMC is needed for strategically searching autobiographical memory.

In order to examine these issues we had high- and low-WMC individuals perform a variant of Williams and Hollan's (1981); see also Bahrick et al., 1975; Bond & Brockett, 1987) autobiographical naming task. Specifically participants were required to name all of their friends from the social networking website facebook.com. Facebook was chosen because it is a commonly used social networking site for college students who make up our sample, and it provides an easy way to determine the number of friends an individual has on the site. After attempting to name all of their friends on Facebook, participants provided information on each response. Specifically, participants indicated how they knew each person (e.g., college room-mate, high school team-mate, study partner, etc.). This information was then used to determine whether participants clustered related information (e.g., recalled all of their fraternity brothers successively), the number of these clusters, the size of these clusters, as well the inter-response times associated with recalling names. Furthermore this information was used to determine the different types of contexts (e.g., dorm-mates, same classes, same intramural softball team, etc.) participants might use in recalling friends, as well as the relative proportion with which different contexts get searched. Finally all of this information was examined as a function of WMC to determine if WMC is needed for strategically searching autobiographical memory in a more naturalistic and ecologically valid setting than has been done before. That is, in Rosen and Engle (1997) participants were told to generate animal names and clusters were defined based an algorithm that looked for inter-response time differences between words. Thus there was no examination of the contents of the actual clusters to see if high- and low-WMC differed qualitatively in the nature of the clusters they generated. Importantly no study has directly examined the role of WMC in autobiographical retrieval and no study has examined the extent to which individual differences in WMC are related to individual differences in autobiographical retrieval and strategic search abilities.

METHOD

Participants and WMC screening

Participants were recruited from the participant pool at the University of Georgia. Individuals were selected based on a composite of the three complex span tasks. Only participants falling in the upper (high-WMC) and lower (low-WMC) quartiles of the composite distribution were selected.

Operation span. Participants solved a series of maths operations while trying to remember a set of unrelated letters that were presented for 1 second each. Immediately after the letter was presented the next operation was presented. Three trials of each list length (3–7) were presented, with the order of list length varying randomly. At recall letters from the current set were recalled in the correct order by clicking on the appropriate letters. For all of the span measures the score was the proportion of correct items in the correct position (for more task details see Unsworth, Heitz, Schrock, & Engle, 2005).

Symmetry span. Participants were required to recall sequences of red squares within a matrix while performing a symmetry judgement task. In the symmetry judgement task participants were shown an 8×8 matrix with some squares filled in black. Participants decided whether the design was symmetrical about its vertical axis. The pattern was symmetrical half of the time. Immediately after determining whether the pattern was symmetrical, participants were presented with a 4×4 matrix with one of the cells filled in red for 650 ms. At recall, participants recalled the sequence of red-square locations in the preceding displays, in the order they appeared, by clicking on the cells of an empty matrix. There were three trials of each list length with list length ranging from 2 to 5.

Reading span. Participants were required to read sentences while trying to remember the same set of unrelated letters as for Operation span. For this task participants read a sentence and determined whether the sentence made sense or not. Half of the sentences made sense while the other half did not. Nonsense sentences were made by simply changing one word from an otherwise normal sentence. After participants indicated whether the sentence made sense or not, they were presented with a letter for 1 second. At recall, letters from the current set were recalled in the correct order by clicking on the appropriate letters. There were three trials of each list length with list length ranging from 3 to 7.

Composite score

For the composite score, scores for the three complex span tasks were z-transformed for each participant. These z-scores were then averaged together and quartiles were computed from the averaged distribution. Participants were 24 high-WMC individuals (z-WMC = .891, SD = .15) and 21 low-WMC individuals (z-WMC = -1.04, SD = .50), as determined by the composite measure. The mean age for both groups was 18.7 years.

Friend recall

Participants were instructed that they would be recalling as many of their listed friends on Facebook as possible in 8 minutes (Bahrick et al., 1975). Participants were informed that they could recall the names in any order they wished. Participants were required to type in each name (first and last) and then press ENTER to record the name. Participants were instructed that they needed to keep trying to recall names throughout the entire 8-minute recall period.

Following the recall task participants were given a spreadsheet containing their responses to the recall task along with various categories for classification. These categories included college, high school, and other (e.g., family members, friends from work, etc.). College was further broken down into dorm, class, social group, and team. High school was further broken down into class, social group, and team. Participants were instructed to classify each response in terms of whether they knew the person from college, high school, both, or other. Furthermore, for college and high school, participants were instructed to classify how they knew the person in terms of whether they knew them from their dorm, from shared classes, from different social groups (e.g., clubs, sororities, fraternities, church, etc.), or from various teams (e.g., intramural sports teams). Participants were instructed to classify each individual according to all the categories they fitted into. Thus, if participants knew a given individual from multiple different contexts (i.e., high school and college, classes and social groups), they were instructed to indicate all of these. In addition to the basic classification scheme participants were also given a column to provide a more detailed explanation for each person and were encouraged to provide as much information as possible. Thus, immediately after the recall task, participants provided detailed information on their responses and this information was used to code the data (Burgess & Shallice, 1996). Participants were given as much time as they needed to perform the classification aspect of the experiment. All of the information obtained from this procedure was then used to determine how participants organised their recall in terms of different clusters based on shared contexts between successively recalled items. Upon leaving the laboratory all participants added the laboratory Facebook account as a friend, so that we could verify the names and determine the number of friends each participant had.

RESULTS AND DISCUSSION

Overall results in the form of the cumulative number of names recalled as a function of time and WMC are shown in Figure 1a. An examination of these cumulative recall functions suggests a number of important findings. First, high-WMC individuals recalled more friend names than low-WMC individuals. Second, high-WMC individuals seem to be recalling names at a faster rate than low-WMC individuals. Third, the rate of recall slows towards the end of the recall period despite the fact that individuals are still recalling items. That is, the rate of recall is a negatively accelerating function (Bousfield & Sedgewick, 1944).

A more fine-grained analysis validated these impressions. Specifically, as shown in Table 1,

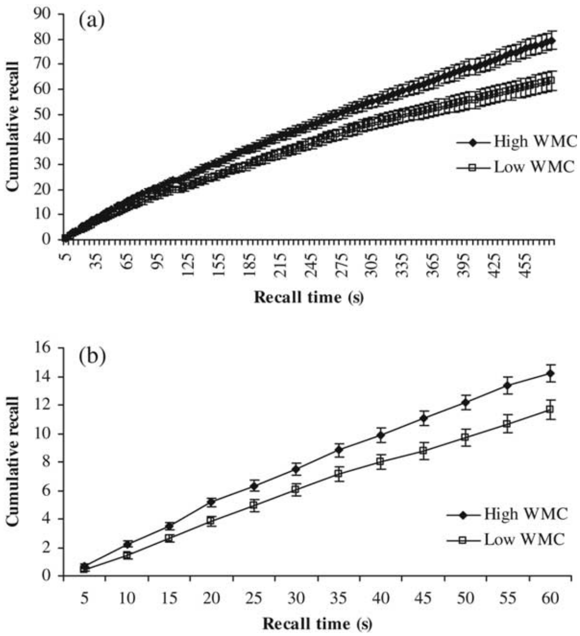

Figure 1. Mean cumulative number of items recalled as a function of recall in seconds and working memory capacity (WMC) (a) for the entire 8-minute recall period and (b) for only the first minute of the recall period. Error bars reflect one standard error of the mean.

high-WMC individuals recalled significantly more friends than low-WMC individuals, $t(43) = 2.78$, $p < .01$, $\eta^2 = .15$. This occurred even though high- and low-WMC individuals had approximately the same number of friends on Facebook, $t < 1$.[2] That is, high- and low-WMC individuals were searching through roughly the same number of items in memory, but high-WMC individuals were better at accessing that information.

In order to examine these overall recall differences in more detail we examined the number of clusters each individual recalled as well as the size of each cluster. Here clusters refer to two or more items recalled from the same context (e.g., fraternity brothers) in succession. Thus participants' own coding was used to determine the number and size of clusters. Importantly this should give an indication of the number of contexts that are self-generated as well as the ability to search within a context. As can be seen in Table 1, high-WMC individuals recalled more clusters, $t(43) = 2.17$, $p < .05$, $\eta^2 = .10$, and had larger cluster sizes, $t(43) = 2.77$, $p < .01$, $\eta^2 = .15$, than low-WMC individuals. Thus high-WMC individuals self-generated more contexts to search and were better at searching within a context than low-WMC individuals, leading to better overall recall.[3] This suggests that high-WMC individuals' recall was more organised than low-WMC individuals' recall. Indeed, an examination of the proportion of random items recalled (i.e., items not associated with a cluster), suggested that low-WMC individuals recalled a higher proportion of random items ($M = .30$, $SE = .04$) than high-WMC individuals ($M = .20$, $SE = .03$), $t(43) = 2.30$, $p < .05$, $\eta^2 = .11$. In fact, for many of these items, low-WMC individuals were more likely than high-WMC individuals to specifically indicate that the name "randomly popped" into their head. Overall, these results are quite consistent with the notion that high-WMC individuals are better at strategically searching their autobiographical memories than low-WMC individuals.

An analysis of recall latency variables should provide additional evidence for differences in the efficiency of searching memory. As shown in Figure 1a, high- and low-WMC individuals generated different cumulative recall functions suggesting differences in the effectiveness of their search processes. Beginning with the work of Bousfield and colleagues (Bousfield & Sedgewick, 1944; see also McGill, 1963; Wixted & Rohrer, 1994), research has found that cumulative recall functions are well described by the cumulative exponential

$$\mathrm{F(t)} = \mathrm{N}(1 - e^{-\lambda \mathrm{t}}), \tag{1}$$

where F(t) represents the cumulative number of items recalled by time t, N represents asymptotic recall, and λ represents the rate of approach to asymptote. Prior research with this type of task has found that individuals who recall more items (i.e., have a larger N) also recall those items at a faster rate (i.e., have a lower λ) than individuals who recall fewer items (Johnson, Johnson, & Mark, 1951). To examine this in the current study we fitted Equation 1 to the cumulative recall functions for the high- and low-WMC groups. In

[2] All analyses were redone covarying out the total number of friends. The results were identical to those reported.

[3] WMC differences in the number of clusters and cluster size were not likely due to differences in whether participants remembered where they knew people from. All participants provided detailed information for each name recalled. What differed between high- and low-WMC individuals was whether successively recalled names came from the same or different contexts (i.e., clusters).

TABLE 1
Recall measures for the entire 8-minute recall period as a function of WMC

	Measure					
WMC	*No. recall*	*No. friends*	*No. clusters*	*Cluster size*	*IRT*	*Time-to-first*
High	81.92 (3.97)	710.08 (61.70)	16.63 (.90)	3.99 (.18)	6.22 (.38)	5.4 (1.05)
Low	66.52 (3.79)	657.71 (70.63)	13.81 (.93)	3.36 (.12)	7.92 (.64)	5.8 (.48)

IRT = inter-response time. Standard errors are shown in parentheses.

both cases the cumulative exponential provided an excellent fit to the data (both R^2s = .99). Examining the resulting parameter estimates suggested that high-WMC individuals recall at a slower rate ($\lambda = .006$, 95% CI = .0057–.0062) than low-WMC individuals ($\lambda = .008$, 95% CI = .0076–.0081). This suggests that high-WMC individuals search autobiographical memory more efficiently than low-WMC individuals.

Although the cumulative recall function provides a general depiction of recall latency, a more detailed analysis of first recall latency and IRTs is necessary to more fully understand search efficiency. In particular an examination of first recall latency and inter-response times should provide important information regarding the ease of searching within contexts and accessing names. An examination of recall latency as a function of WMC suggested that high- and low-WMC individuals started out recalling at the same time, but high-WMC individuals recalled at a faster rate than low-WMC individuals thereafter. Specifically, as shown in Table 1, high- and low-WMC individuals both started their recall after approximately 5 seconds (i.e., time-to-first recall), $t < 1$, but thereafter high-WMC individuals' inter-response times (IRTs) were faster than low-WMC individuals' IRTs, $t(43) = 2.34$, $p < .05$, $\eta^2 = .11$. These results are consistent with the notion that high-WMC individuals are more efficient at searching their memory than low-WMC individuals, in that the cues high-WMC individuals use better focus their search leading to quicker access to the desired information.

A possible issue with the results reported thus far is that they are for recall over the entire 8-minute period. Perhaps the differences between high- and low-WMC individuals is simply due to the fact that low-WMC individuals are fatigued or bored throughout the recall period and thus are less willing to continue recalling. That is, the results may be due to variables associated with the long recall period, rather than actual differences in search. To examine this issue, we analysed the data for only the first minute of the recall period, where such factors should not be an issue. Shown in Figure 1b are the cumulative recall functions for high- and low-WMC individuals for the first minute. As shown in Table 2, high- and low-WMC individuals differed in the total number of names recalled, the number of clusters recalled, the size of the clusters, as well as IRTs even in the first minute, all ts > 2.10, all p's < .05, all η^2s > .09. Thus the overall pattern of results suggesting recall differences between high- and low-WMC individuals occurs even in the first minute of the recall period.

Given overall WMC differences, the final issue to examine was the nature of the recalled items in terms of what contexts they are from and whether high- and low-WMC individuals differ in the contexts from which these items are recalled from. Specifically, for each individual we computed the proportion of friends recalled that were classified as college friends, high school friends, or other. As shown in Table 3 more friends were recalled from either college or high school compared to other acquaintances (both ts > 6.04, ps < .01), but there was no difference in the proportion of friends recalled from college and high school, $t < 1$. As shown in Table 3 there were no WMC differences in the proportion of friends recalled from college, high school, or other acquaintances, all ts < 1.4, all ps > .25. Thus, when searching for friends' names, participants primarily

TABLE 2
Recall measures for only the first minute of the recall period as a function of WMC

	Measure			
WMC	*No. recall*	*No. clusters*	*Cluster size*	*IRT*
High	14.21 (.62)	3.54 (.25)	4.38 (.45)	4.09 (.17)
Low	11.67 (.63)	2.81 (.26)	3.15 (.15)	5.26 (.42)

IRT = inter-response time. Standard errors are shown in parentheses.

TABLE 3
Proportion of friends recalled from college, high school, and other as a function of WMC

WMC	*College*	*High school*	*Other*
High	.40 (.03)	.51 (.04)	.09 (.03)
Low	.44 (.06)	.43 (.06)	.14 (.05)

Proportions of friends recalled can sum to greater than 1.0 because participants were allowed to report knowing someone from multiple contexts (i.e., both a high school and a college friend). Standard errors are shown in parentheses.

relied on self-generated contexts associated with school rather than other contexts (i.e., work).

We also examined college and high school friends in more detail to determine where these friends were being recalled from and whether high- and low-WMC individuals differed. Shown in Table 4 are the proportion of college and high school friends recalled, broken down into separate categories. These categories included: dorm-mates (for college only), shared classes, shared social groups (e.g., sororities and fraternities), shared teams (e.g., same intramural team), or other (friends not classified into the other categories). For college friends, participants tended to recall friends who were dorm-mates, friends from different social groups (e.g., sororities and fraternities), or friends who were not from any of the specified categories. Far fewer friends were recalled from classes or teams. Overall these results are very much in line with prior research examining the different contexts individuals use to search autobiographical memory in this type of task (Bahrick et al., 1975; Bond & Brockett, 1987; Brewer et al., 2005). Importantly, high- and low-WMC individuals did not differ in the proportion of friends recalled from any of these categories, all ts < 1, all ps $> .33$. For high school friends, most friends were people from shared classes (e.g., same biology class) or people who knew the participant some other way (e.g., friend of a friend) than from social groups or teams. Again, high- and low-WMC individuals did not differ in the proportion of friends recalled from any of these categories, all ts < 1, all ps $> .54$. Thus, although high-WMC individuals recalled more contexts and more friends per context than low-WMC individuals, high- and low-WMC individuals did not differ in the nature of the contexts recalled. That is, high- and low-WMC individuals had qualitatively similar recall profiles, but high-WMC individuals were better overall at searching their memories than low-WMC individuals.

SUMMARY AND CONCLUSIONS

The current study examined the role of WMC in strategic search from autobiographical memory. High- and low-WMC individuals recalled as many of their friends on Facebook as possible in 8 minutes. It was found that high-WMC individuals recalled more friends, more clusters (contexts) of friends, had more friends per cluster, and recalled at a faster rate than low-WMC individuals. These results suggest that high-WMC individuals were better at self-generating contexts to search through and better at searching within a context than low-WMC individuals. Furthermore, high-WMC individuals' overall recall was more organised than low-WMC individuals. These results are qualitatively similar to those obtained by Rosen and Engle (1997) examining the role of WMC in semantic memory search. Specifically Rosen and Engle found that high-WMC individuals recalled more animal names, recalled more clusters of animals, had larger cluster sizes, and recalled at a faster rate, than low-WMC individuals. The current results extend those from Rosen and Engle by demonstrating similar patterns of results in an autobiographical (personal) memory task in which the nature of the clusters was specifically examined for high- and low-WMC individuals. It should be noted that the current autobiographical memory task is a semantic-autobiographical task. Future

TABLE 4
Proportion of friends recalled from college and high school broken down into specific categories as a function of WMC

	College					*High school*			
WMC	*Dorm*	*Class*	*Social*	*Team*	*Other*	*Class*	*Social*	*Team*	*Other*
High	.28 (.06)	.18 (.06)	.28 (.07)	.07 (.03)	.27 (.06)	.31 (.07)	.11 (.03)	.13 (.03)	.52 (.07)
Low	.22 (.05)	.11 (.04)	.28 (.08)	.03 (.03)	.37 (.08)	.31 (.07)	.08 (.03)	.12 (.05)	.50 (.08)

Proportions of friends recalled can sum to greater than 1.0 because participants were allowed to report knowing someone from multiple contexts (i.e., both a high school and a college friend). Standard errors are shown in parentheses.

work should examine these issues with episodic-autobiographical memory task. Collectively, the current results suggest that WMC is important for strategically searching memory overall and is not task/system specific.

Importantly, although high-WMC individuals recalled more friends than low-WMC individuals, high- and low-WMC individuals tended to use the same contexts as search cues. For example, both high- and low-WMC individuals were equally likely to recall college friends based on shared living environments (i.e., dorm-mates) as well as recall friends from different social groups (e.g., sorority sisters). Thus high-WMC individuals were better at cue elaboration and self-generating different contexts to use as cues than low-WMC individuals, but when low-WMC individuals did generate a context, it was the same as those generated by high-WMC individuals. This suggests that a key difference between high- and low-WMC individuals in retrieval is the ability to self-generate cues during the cue elaboration phase in a generative retrieval task. If cues are present that adequately access the desired information, then WMC will not be needed.

These results are also consistent with models of autobiographical search that suggest that first you must self-generate retrieval cues in the form of different contexts, then you search those contexts for information, and finally you verify or monitor the products of the search (Reiser et al., 1985; Whitten & Leonard, 1981; Williams & Hollan, 1981). In the current study participants used retrieval strategies to self-generate different contexts (dorms, social groups, classes, teams, etc.) that would include the desired information (i.e., friend names) similar to the results of Williams and Hollan (1981) and others (Bahrick et al., 1975; Bond & Brockett, 1987; Brewer et al., 2005). Participants then used these contexts to search and generate clusters of related items similar to what is typically found when searching semantic memory. For instance, when searching for friends from college, participants were more likely to generate contexts based on shared living environments and shared associations to a particular social group, whereas when searching for friends from high school, participants were more likely to generate contexts based on shared classes. Importantly the current results suggest that these strategic search processes are reliant on an individual's WMC. That is, the role of WMC is to self-generate different contexts to use as retrieval cues for search and to use the products of the search to generate additional information leading to clusters of related items.

Overall, the results of the current study are consistent with the notion that working memory control processes are needed for strategically searching autobiographical memory (Conway, 1992). Importantly the current results provide the first detailed demonstration that WMC is needed for searching autobiographical memory and that individual differences in WMC are related to autobiographical retrieval. Furthermore, the results are consistent with the notion that WMC is needed not only to actively maintain representations over the short-term, but WMC is also needed when one is strategically searching their memory system regardless of whether the information is autobiographical (personal), semantic, or episodic in nature.

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