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Aging and Directed Forgetting in Episodic Memory: A Meta-Analysis

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Abstract

This meta-analysis examines the effects of aging on directed forgetting. A cue to forget is more effective in younger ($d = 1.17$) than in older adults ($d = 0.81$). Directed-forgetting effects were larger: (a) with the item method rather than the list method; (b) with longer presentation times; (c) with longer postcue rehearsal times; (d) with single words rather than verbal action phrases as stimuli; (e) with shorter lists; and (f) when recall rather than recognition was tested. Age effects were reliably larger when the item method was used, suggesting that these effects are mainly due to encoding differences.

In this paper, we provide a meta-analytic overview of studies of aging and directed forgetting. The term forgetting often has a negative connotation, especially in the context of aging. Forgetting, however, is not always a failure of memory – sometimes forgetting is desirable. Imagine, for instance, that one of your colleagues has recently remarried, and you welcome her husband with the name of the man she just divorced. When performed intentionally, forgetting may prevent outdated information from interfering with the encoding and retrieval of currently relevant information. The experimental paradigm used most often to study intentional forgetting in episodic memory is the directed-forgetting paradigm (for reviews, see Johnson, 1994, and MacLeod, 1998). In the directed-forgetting paradigm, participants are presented with a set of items, some of which are cued to be remembered for a later memory test (these are labelled TBR items) and others that are cued to be forgotten (TBF items). Memory is unexpectedly tested for all items and is usually worse for TBF than TBR items.

Directed forgetting has initially received some attention in the field of cognitive aging due to its ties to an inhibition account of age-related changes in memory (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; Zacks, Radvansky, & Hasher, 1996; Zacks & Hasher, 1994). The inhibition theory claims that older adults have difficulties in inhibiting the processing of goal-irrelevant information (e.g., TBF-items). There are, however, several inhibitory and non-inhibitory explanations of directed forgetting pointing at differences between cueing methods used in a study (Basden, Basden, & Gargano, 1993; Sahakyan & Foster, 2009).

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A cue to forget can be applied either on an item-by-item basis, that is, each word is individually cued as TBF or TBR, or to a whole list or block of items at once. In list-method studies a first list is presented followed by either a cue to forget or a cue to continue remembering this first list while studying a second list (Bjork, 1972; Block, 1971; Elmes, Adams, & Roediger, 1970; Muther, 1965). In item-method studies, the directed-forgetting effect usually refers to a within-subjects comparison; recall of TBF items is lower than recall of TBR items. In list-method studies the directed-forgetting effect usually refers to a between-subjects comparison; forget-cue participants typically show impaired List 1 recall compared to remember-cue participants, as well as improved List 2 recall, known as the costs and the benefits of directed forgetting, respectively (Bjork, 1972; Block, 1971; Elmes et al., 1970; Muther, 1965; Sahakyan & Delaney, 2003).

Item-method directed forgetting is proposed to reflect differential encoding of TBR and TBF items, selective rehearsal favoring the TBR items, and/or partitioning of TBR and TBF items into distinctive memory sets -- all mechanisms operating during the encoding phase, ensuring that TBR items become more available than TBF items for later remembering (Basden & Basden, 1996, 1998; Basden et al., 1993; Bjork, Bjork, & Anderson, 1998; Bjork, 1972; Epstein, 1972; MacLeod, 1999; Sahakyan & Foster, 2009; Spector, Laughery, & Finkelman, 1973; Wetzel, 1975; Wetzel & Hunt, 1977). The inhibition framework suggests that attentional inhibition of the TBF items at encoding allows for the release of processing resources which are then applied to more elaborate encoding of the TBR items (Zacks & Hasher, 1994; Zacks et al., 1996).

For list-method cueing, mainly retrieval-based mechanisms have been suggested, because the forget cue is given after an entire list has already been encoded (Bäuml, 2008; Basden et al., 1993; Geiselman, Bjork, & Fishman, 1983; Goernert & Larson, 1994; Sahakyan & Delaney, 2003; Sahakyan, Delaney, & Waldum, 2008b; Sahakyan & Kelley, 2002; Whetstone, Cross, & Whetstone, 1996). The retrieval-inhibition account (Bjork, 1989) claims that following a forget cue, an inhibitory mechanism blocks the access to List 1 items (producing the costs of directed forgetting), thereby reducing proactive interference from List 1 items on List 2 items (producing the benefits of directed forgetting). Another inhibition account suggests that List 1 items are inhibited when these come to mind during List 2 encoding in the forget condition (Conway, 2001).

Some accounts for list -method directed forgetting, however, have proposed at least a partial role of encoding. In their contextual account, Sahakyan and Kelley (2002) claim that a forget cue brings subjects to initiate a mental context change. This produces a mismatch between List 1 study context and retrieval context, leading to a directed forgetting cost; List 2 recall is improved due to reduced interference. In the dual-factor extension of the contextual account, the benefits in List 2 recall are instead ascribed to improved encoding strategies following a forget cue (Sahakyan, 2004; Sahakyan & Delaney, 2003; Sahakyan & Delaney, 2005). There is also an encoding-based selective rehearsal account of list method directed forgetting (e.g., Benjamin, 2006; Sheard & MacLeod, 2005). This theory states that the costs arise because in forget conditions the first list is not rehearsed after the cue; the benefits arise because the second list is rehearsed exclusively. The importance of rehearsal differences, however, can be questioned given that the directed-forgetting effect as tested by recognition appears to be restricted to the item method (Bjork et al., 1998; Geiselman et al., 1983). In the list method, performance in the remember and forget groups is often identical, suggesting that List 1 has been rehearsed to the same extent by both groups (but see Benjamin, 2006; Sahakyan & Delaney, 2005; and Sahakyan, Waldum, Benjamin, & Bickett, 2009).

The inhibitory account of cognitive aging would predict that older adults' directed forgetting should be reduced under both the item method and the list method (Hasher et al., 1999), due to older adult's failure to inhibit the processing of information cued to be forgotten. A survey of the literature on directed forgetting and aging reveals, however, that the majority of studies showing age-related effects appear to be item-method studies (e.g., Collette, Germain, Hogge, & Van der Linden, 2009; Dulaney, Marks & Link, 2004; Earles & Kersten, 2002; Hogge, Adam, & Collette, 2008; Salthouse, Siedlecki, & Krueger, 2006; Sego, Golding, & Gottlob, 2006, Exp. 1A; Witthöft, Sander, Süß, & Wittmann, in press; Zacks et al., 1996, Exp. 1A, Exp. 1B). In list method studies, age-related equivalence seem to prevail (e.g., Sahakyan, Delaney, & Goodmon, 2008a, Exp. 1 and Exp. 2 with standard directed forgetting instructions; Sego et al., 2006, Exp. 2A, 2B; Zellner & Bäuml, 2006, Exp. 1-3); there are, however, exceptions to this pattern (Gamboz & Russo, 2002; Pavur, Comeaux, & Zeringue, 1984; Sahakyan et al., 2008a, Exp. 1, Exp 2: context change instructions; Zacks et al., 1996, Exp. 2, 3). One possible explanation for varying age-related effects in list-method studies is strategic behavior. Sahakyan et al. (2008a) suggest that whether older adults will show directed-forgetting costs in list-method studies depends on whether they engage in active forgetting strategies; such strategies are a prerequisite to initiate a mental context change. If older adults' memory monitoring yields optimistic predictions of future recall, they would be likely to initiate strategic behaviors to comply with forgetting instructions. Such strategic behavior is likely to depend on factors that influence older adults' memory performance and metamemory in general, for instance pre-existing associations between items (Naveh-Benjamin, Brav, & Levy, 2007), item presentation time (Salthouse, 1996), or list length (Kahana, Dolan, Sauder, & Wingfield, 2005; Smith, 1979).

The costs of directed forgetting have attracted greater interest in aging research than the benefits (for which we were able to locate only three studies: Sahakyan et al., 2008a; Sego et al., 2006, and Zellner & Bäuml, 2006), presumably because of the possible link to age differences in inhibition and the suppression of information; in item-method studies usually only the costs are scored using the TBR-TBF difference in recall (but see Sahakyan & Foster, 2009). This latter score leads, however, to the question whether smaller TBR-TBF differences in older adults are informative about age differences in forgetting or about age differences in encoding and intentional recollection of TBR items. In an individual-differences study, Salthouse et al. (2006) reported that controlling for age-related differences in TBR scores reduced semi-partial correlations between age and TBF scores essentially to zero (-.03 for words and .06 for pictures). This implies that age-related effects in directed forgetting might be largely attributable to age differences in how TBR items are processed and recalled.

To date, the pattern of results with respect to age effects in directed forgetting is mixed. Recent studies suggest that age effects may mainly occur in item-method studies, pointing at the importance of age differences in encoding and intentional recollection of TBR items rather than in the suppression of TBF items. The goal of this meta-analysis is to bring together the available data on age effects in directed forgetting to test if older adults' directed-forgetting effects are indeed smaller than those of younger adults (even after adjusting for baseline differences in TBR recall), as expected from an inhibitory viewpoint, or whether age effects in directed forgetting depend on the cueing method or other moderators.

Method

Sample of studies

Studies were collected using an internet-based search strategy, as well as through personal contacts. The internet based search involved Science Direct databases (PsycInfo, PsycArticles), Google Scholar, and Scribd. The key terms were (1) *directed forgetting* and *aging*, (2) *intentional forgetting* and *aging*, (3) *directed forgetting elderly*, and (4) *intentional forgetting elderly*. In addition, we checked the references in each of the collected articles for studies overlooked. We concluded our search in February 2009. Studies were included if they examined at least one sample of younger (mean age < 30 years) and one sample of older (mean age > 60 years) adults; if the data were reported in a format amenable to meta-analysis (e.g., mean and standard deviation or standard error, *F* ratio, *t* test, standardized difference); if the study was published in the English language in a peer-reviewed journal; and if the dependent measure pertains to episodic memory accuracy (this excluded studies which applied short-term-memory paradigms, typically yielding latency measures; Oberauer, 2001, 2005a, 2005b; Witthöft et al., in press; Zacks et al., 1996, Exp. 3); and if the scoring allowed for a comparison between TBR and TBF material (this excluded Andrés, Van der Linden, & Parmentier, 2004; one experimental condition from Collette et al., 2009; Collette, Schmidt, Scherrer, Adam, & Salmon, 2007; Pavur et al., 1984). The final sample consisted of 10 articles, containing 24 different experiments or independent subject groups; the studies are reported in Table 1. For each of the included studies we recorded the following variables: age, number of participants, cueing method (item or list), number of TBR and TBF stimuli per list[1], presentation time per item, postcue rehearsal time, response modality (oral, written, or keypress), recall time (free or limited), type of test (recall or recognition), stimulus presentation modality (auditory or visual), presentation format (computer-based, CD-player, or written cards), duration of the delay from study to recall, stimulus associations (TBF-TBR unrelated or associated), and stimulus type (single words or verbal action phrases).

Data analysis

The main focus of the analyses is on a potential age-differential effectiveness of a forget cue in item vs. list method studies in the costs of directed forgetting. One problem is that item method studies use a within-subject design; most list-method studies use a between-subject design (Zacks et al., 1996, is the exception). We therefore used the correction factors suggested by Morris and DeShon (2002) to treat the list-methods' independent-group measures as if they were repeated-measures designs. This method necessitates an estimate of the correlation between TBR and TBF items. Only the Salthouse et al. (2006) study provided this correlation (r = .13, averaged over measures, derived from 195 subjects). This correlation may seem low, but there is corroborating evidence of its general magnitude: Collette et al. (2009) report a zero correlation (r = -.06) between the directed-forgetting effect and TBR items in their task.

Two types of analyses were conducted. First, traditional effect size analysis (Hedges & Olkin, 1985) was used to determine the size of the directed-forgetting effect in the different age groups. Size of the effect was expressed as the mean standardized difference, that is, the mean of the accuracy for the TBR items minus the mean of the accuracy for TBF items, divided by the pooled standard deviation, done for each age group in each study separately. When mean or SD were not reported, inferential statistics, if available, were used to determine effect sizes. Overall effect sizes for each age group as well as separate average effect sizes for specific contrasts of interest were calculated. Similarly, we calculated the size of the age effect within the TBR items for each of the studies as mean standardized difference. To maintain independence of effect sizes, so that Type-I error rate can be minimized, multiple effects within each independent subject group were averaged. After averaging, the effect sizes were corrected for small sample bias as outlined by Hedges and Olkin (1985). Pooling of effect sizes within each grouping of interest was done by calculating a mean weighted effect size (d_+), weighting for sample size, as outlined in Hedges and Olkin (1985).

[1]The number of TBF items and TBR items is matched in most of the studies and means the number of items per list presented at once in an experimental session. Zacks et al. (1996) have, however, used a block-wise presentation of items in which the number of TBF and TBR items differs within the blocks (e.g., blocks including 0 TBF-4 TBR items and 1 TBF-3 TBR items). In their Experiment 1, items were presented in 6 lists including 24 words each. We therefore used a number of 12 items per list (12 TBF, 12 TBR) for Experiment 1A and 1B. In their Experiment 2, the authors have used 15 lists and the number of TBF and TBR items differed overall: participants have on average seen 7 item per list; we used therefore a number of 3.5 TBF and TBR items per list.

Second, a weighted least-squares multiple regression analysis (as adapted for use with effect sizes as dependent variables; Hedges & Olkin, 1985) was used to investigate the possible influence of the whole set of moderator variables as well as the influence of age and its interactions with the different moderator variables on the directed forgetting effects as obtained in the first set of analyses.

Results

Effect sizes for the individual studies are reported in Table 1. The weighted mean effect size for directed forgetting, that is, the mean standardized difference in memory performance for TBF and TBR items was 1.17 for younger adults (the 95% confidence interval [CI] ranged from 1.06 to 1.29), and for old adults 0.81 (the 95% CI ranged from 0.70 to 0.92), thus indicating that the effect size was larger than zero in both age groups. The between-groups homogeneity statistic was significant, Q_B (1) = 20.45, $p < .001$, indicating that the directed-forgetting effect was reliably larger in younger adults than in older adults. Effect sizes for both young and old adults were, however, also, heterogeneous, as indicated by the significant within-group homogeneity statistic, Q_W (23) = 2,221.47, $p < .001$, and 82.95, $p < .001$, respectively. This indicates considerable variability in effect sizes and warrants the examination of the influence of potential moderator variables in a regression.

We investigated the influence of all moderator variables simultaneously in a multiple regression procedure. We only entered potential moderator variables (dummy coded where appropriate) that were present in all studies (see Table 2); these are: age group (0 = younger; 1 = older), cueing method (0 = list; 1 = item), presentation time per item in seconds, postcue rehearsal time in seconds, stimulus presentation modality (0 = visual; 1 = auditory), duration of the delay from study to recall in seconds, number of stimuli per list, and stimulus type (0 = words; 1 = verbal action phrases); the regression model also included all possible interactions between age group and the other moderators. Additionally, the age effect in TBR performance was entered as a control variable (0 for younger adults; its actual value in *d* units for older adults); this allows us to estimate the effect of age on directed forgetting over and beyond the effect age has on item memory (see Salthouse et al., 2006). This full model was then pruned by deleting all variables with non-significant regression weights. The final regression model (including the age effect in TBR as a control variable) is represented in Table 3. The model fit the data well, $R^2 = 0.63$. The mean predicted effect size was 0.98. Directed forgetting effects were larger when participants were younger adults rather than older adults, when the item method was used rather than the list method, when presentation time was longer, when the postcue rehearsal time was longer, when single words were used rather than verbal action phrases, and when the number of TBF and TBR stimuli in a lists is small (short lists). Only one potential moderator interacted with age group: The age effect was reliably larger when the item method was used: Employing the item method increased the young-old difference in directed forgetting by 0.53 *d*-units compared to the list method. To follow up on the latter finding, we calculated mean weighted effect sizes for each age group for each method separately. For the item method, the mean directed-forgetting effect was 1.71 for younger adults and 1.11 for older adults; the difference was reliable, Q_B (1) = 26.92, $p < .001$. For the list method, the mean directed-forgetting effect was 0.71 for younger adults and 0.51 for older adults; the difference was marginally reliable, Q_B (1) = 3.01, $p = .08$. Thus, list method studies show a smaller, only marginally significant age difference in directed forgetting.

Not all studies included recall-only or recognition-only conditions (e.g., Hogge et al., 2008). Given the importance of this moderator variable in particular with respect to the controversy whether TBF-TBR encoding differences might play a role for list method directed forgetting as well as for item method studies (see Benjamin, 2006; Sahakyan and Delaney, 2005; Sahakyan et al., 2009), testing the interaction between the type of memory test and cueing method (item vs. list) and its interaction with age would have been fruitful, but there were only two data points for item method recognition (see Table 2), making an analysis infeasible. To test for the general influence of type of test on directed-forgetting effects and potential interactions with age, we reran the analysis with those studies that include recall-only or recognition-only conditions (42 data points), adding a dummy term for memory test (recall vs. recognition) and its interaction with age. This model fit the data well ($R^2 = .73$, after trimming). The recall-recognition dummy was significant (after trimming: $B = -0.48$; $p < .01$; beta = -0.22); the interaction with age was not (full model: $p = .71$); the rest of the pattern of significances replicated the earlier model. Thus, recognition decreased the directed-forgetting effect by about 1/2 standard deviation, but this effect did not differ reliably across age groups.

Discussion

The main result of the present meta-analysis is straightforward: Both younger and older adults show significantly directed forgetting, but the directed-forgetting effect is reliably smaller in older adults than in younger adults, even after controlling for age differences in baseline recall. The age-related impairment in directed forgetting thus cannot be reduced to a more general age-related problem in memory performance, that is, intentional recollection of TBR items. This first result is compatible with an inhibitory account of age effects in directed forgetting (Hasher et al., 1996; Zacks et al., 1996) according to which older adults have problems in inhibiting material cued to be forgotten. Without making additional assumptions, however, a global inhibition framework is hard to reconcile with our second main finding.

Our second main finding yields a clue as to the reason for the age-related deficit in directed forgetting: The age-related effect is reliably larger in item-method studies than in list-method studies. Item-method directed forgetting has been associated with a number of mechanisms such as differential encoding, selective rehearsal, partitioning of items, and attentional inhibition as outlined in the introduction. These mechanisms are all assumed to operate at encoding, rather than at retrieval. This, then, is where the mainstay of the age-related difference in directed forgetting is situated. List method studies, which have mainly been associated with retrieval-based explanations, only yielded a marginally significant age difference in directed forgetting. Given the relatively small number of studies, the cautious conclusion would be that age differences associated with retrieval might play a smaller role in the directed forgetting effect.

On the one hand, the result of much smaller age effects in the item than in the list method casts doubts on assertions that the same mechanism (e.g., different TBR-TBF rehearsal, see Sheard & MacLeod, 2005) is responsible for item and list method directed forgetting. On the other hand, one could still argue that item-method and list-method directed forgetting are caused by a single mechanism, that is, inhibition – inhibition, however, operating at different points in time: at encoding in the item method and at retrieval in the list method. One then has to claim that the access and deletion function of inhibition (as described by Hasher et al., 1999; associated with encoding and retrieval, resp.) are differentially impaired in aging; recent research supports this assertion (e.g., Titz, Behrendt, Menge & Hasselhorn, 2008; Titz, Behrendt, & Hasselhorn, in press).

It is also possible that the item method and the list method induce the same strategic effect at encoding – that is, differential rehearsal of TBF and TBR materials according to instructions (see Benjamin, 2006; Sahakyan et al., 2009; Sheard & MacLeod, 2005) – but that the methods differ in the degree to which they elicit TBF-TBR rehearsal differences (Benjamin, 2006). In the list method, TBF items are likely to receive elaborate rehearsal until the forget cue is displayed, making them harder to forget compared to TBF items studied under the item method, where participants are assumed to stop rehearsal immediately after each TBF cue, rehearsing

TBR items studied earlier instead (Sahakyan & Foster, 2009). Because older adults have a specific deficit in binding item information to contextual elements including item-cue relationships (Kliegl & Lindenberger, 1993; Naveh-Benjamin et al., 2007; Old & Naveh-Benjamin, 2008) they may remember less well which items were TBR and which were TBF so that they mistakenly retrieve earlier TBF instead of TBR items. This might explain why the age effect is smaller in list-method directed-forgetting than item-method-directed forgetting – TBF-TBR confusions are less likely in list-method studies, where a single cue is related to a whole episode of (TBF) items. The phenomenon of older adults' (marginally) smaller list-method directed-forgetting costs might also be due to problems in item-context binding; as a consequence, older adults would suffer less when the recall context differs from the List 1 encoding context (e.g., Sahakyan, 2004).

With the exception of the cueing-method variable, procedural differences between studies did not moderate the age-related effectiveness of a forget cue. Some of these differences, however, did exert an influence on the effectiveness of a forget cue in general (i.e., in both younger and older adults). Directed-forgetting effects were larger with item method cueing, fewer stimuli, longer presentation time, longer postcue intervals, single-word stimuli as opposed to verbal action phrases, and recall as opposed to recognition. The small number of studies should obviously inspire caution with regard to those general results. The number of regressors in our first, exploratory regression is relatively high leading to a low ratio of cases to predictors and thus to low power. Potential moderating variables with a genuine relationship to directed forgetting might therefore be left undetected. Another caveat is that the present meta-analysis includes only published studies; age differences in directed forgetting might therefore be overestimated due to a publication bias.

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Table 1

Studies along with mean age, sample sizes (N), directed forgetting effects (df) and age effects for TBR items

Study	Mean age young	Mean age old	N young	N old	DF effect young	DF effect old	Age effect TBR
Item method studies							
Collette, Germain, Hogge, & Van der Linden (2009)	24.2	67.0	40	40	1.79	1.29	1.08
Dulaney, Marks, & Link (2004, Expt. 1)	24.8	72.4	24	24	0.64	0.29	0.80
Dulaney, Marks, & Link (2004, Expt. 2)	19.1	71.7	20	20	0.44	0.27	0.48
Earles & Kersten (2002, ‘performed’ group)	19.2	73.3	27	27	0.30	0.41	1.47
Earles & Kersten (2002, ‘not performed’ group)	19.2	73.3	27	27	2.62	0.94	1.92
Gamboz & Russo (2002, ‘deep’ condition)	22.0	68.0	10	10	1.58	1.49	1.91
Gamboz & Russo (2002, ‘shallow’ condition)	22.0	68.0	10	10	3.26	1.36	1.68
Gamboz & Russo (2002, ‘control’ condition)	22.0	68.0	10	10	5.26	2.40	2.94
Hogge, Adam, & Collette (2008)	23.6	66.0	33	27	0.95	0.28	0.84
Salthouse, Siedlecki & Krueger (2006)	28.3	70.8	89	106	2.14	1.24	0.84
Sego, Golding & Gottlob (2006) Exp. 1A	19.0	72.2	30	30	4.74	2.00	2.23
Sego, Golding & Gottlob (2006) Exp. 1B	19.0	72.2	30	30	2.29	1.39	0.82
Zacks, Radvansky, & Hasher (1996) Exp. 1A	19.4	68.2	24	24	2.63	1.90	1.64
Zacks, Radvansky, & Hasher (1996) Exp. 1B	21.5	70.6	24	24	2.32	1.91	1.19
List method studies							
Sahakan, Delaney & Goodmon (2008) Exp. 1	20.0	76.9	64	64	0.83	0.25	0.83
Sahakan, Delaney & Goodmon (2008) Exp. 2	19.1	74.7	64	64	0.69	0.64	0.28
Sego, Golding & Gottlob (2006) Exp. 2A[a]	18. 7	71.7	30	30	0.72	0.85	1.57
Sego, Golding & Gottlob (2006) Exp. 2B[a]	18. 7	71.7	30	30	0.53	0.46	3.26
Zacks, Radvansky, & Hasher (1996, Expt. 2, recall)	19.3	70.5	24	24	1.46	0.44	1.11
Zacks, Radvansky, & Hasher (1996, Expt. 2, recog.)	21.7	68.8	24	24	0.89	0.44	0.57
Zellner & Bäumel (2006) Expt. 1	21.3	72.6	18	18	0.86	0.91	1.65
Zellner & Bäumel (2006) Expt. 2, output order 1	22.6	71.2	12	12	0.50	0.72	1.11
Zellner & Bäumel (2006) Expt. 2, output order 2	22.6	71.2	12	12	0.69	0.55	1.31
Zellner & Bäumel (2006) Expt. 3	23.0	69.8	48	48	0.58	0.72	1.10

[a]Directed forgetting effects averaged across tasks (items “to-be-learned” and “items-to-be-judged”); no interaction for memory cue (remember, forget) × list (List 1, List 2) × task (learn; judge) occurred.

Table 2

Recorded variables for the studies present in all studies: cueing method (cueing), presentation time per item in seconds (sec.), test (recall or recognition), stimulus type (stimuli), postcue rehearsal time in seconds (postcue), stimulus presentation modality (modality), duration of the delay from study to recall in seconds (delay), number of TBF/TBR stimuli per list (number)

Study	cueing	sec.	test	stimuli	postcue	modality	delay	number
Collette, Germain, Hogge, & Van der Linden (2009)	item	3	recall	word	3	visual	30	18
Dulaney, Marks, & Link (2004, Expt. 1 recall)	item	3	recall	word	3	visual	90	30
Dulaney, Marks, & Link (2004, Expt. 1 recog)	item	3	recog.	word	3	visual	90	30
Dulaney, Marks, & Link (2004, Expt. 2 recall)	item	3	recall	word	3.17[a]	visual	90	15
Dulaney, Marks, & Link (2004, Expt. 2 recog)	item	3	recog.	word	3.17[a]	visual	90	15
Earles & Kersten (2002, 'performed' group)	item	8	recall	action phrase	6	visual	0	20
Earles & Kersten (2002, 'not performed' group)	item	8	recall	action phrase	6	visual	0	20
Gamboz & Russo (2002, 'deep' condition)	item	5	recall	word	1	visual	30	14
Gamboz & Russo (2002, 'shallow' condition)	item	5	recall	word	1	visual	30	14
Gamboz & Russo (2002, 'control' condition)	item	5	recall	word	1	visual	30	14
Hogge, Adam, & Collette (2008)	item	3	stem-completion	word	4.5	visual	30	32
Sahakan, Delaney & Goodmon (2008) Exp. 1	list	6	recall	action phrase	6	visual	60	12
Sahakan, Delaney & Goodmon (2008) Exp. 2	list	6	recall	action phrase	6	visual	60	12
Salthouse, Siedlecki & Krueger (2006)	item	5	recall	word/pic.	2	visual	0	15
Sego, Golding & Gottlob (2006) Exp. 1A	item	5	recall	word	6	visual	300	12
Sego, Golding & Gottlob (2006) Exp. 1B	item	5	recall	word	6	visual	300	12
Sego, Golding & Gottlob (2006) Exp. 2A	list	5	recall	word	6	visual	300	24
Sego, Golding & Gottlob (2006) Exp. 2B	list	5	recog.	word	6	visual	300	24
Zacks, Radvansky, & Hasher (1996) Exp. 1A	item	5	both recall and recog.	word	1	visual	300	12
Zacks, Radvansky, & Hasher (1996) Exp. 1B	item	5	both recall and recog.	word	1	visual	300	12
Zacks, Radvansky, & Hasher (1996, Expt. 2, recall)	list	5	recall	word	0	visual	0	3.5
Zacks, Radvansky, & Hasher (1996, Expt. 2, recog.)	list	5	recog.	word	0	visual	0	3.5
Zellner & Bäumel (2006) Expt. 1	list	3	recall	word	0	visual	120	12
Zellner & Bäumel (2006) Expt. 2, output order 1	list	2	recog.	word	0	auditory	120	10
Zellner & Bäumel (2006) Expt. 2, output order 2	list	2	recall	word	0	auditory	120	10
Zellner & Bäumel (2006) Expt. 3	list	2	recall	word	0	auditory	120	10

[a] averaged across three conditions

Table 3

Final model of the inverse variance weighted regression for directed forgetting effects in younger and older adults

	Regression coefficients			
	B	**SE**	**P**	**Beta**
Constant	0.52	0.21	.014	0.00
Age group	-0.45	0.15	.003	-0.31
Age effect on TBR items	0.23	0.10	.014	0.24
Cueing method	1.25	0.14	.000	0.86
Presentation time	0.18	0.04	.000	0.39
Postcue rehearsal time	0.01	0.00	.000	0.50
Stimulus type	-1.29	0.22	.000	-0.79
List length	-0.04	0.01	.000	-0.38
Age group by cueing method	-0.53	0.16	.001	-0.33

Note. Age group (0 = younger; 1 = older), cueing method (0 = list; 1 = item), stimulus type (0 = single words; 1 = verbal action phrases), TBR = to-be-remembered