Marche, T. A., Howe, M. L., Lane, D. G., Owre, K. P. & Briere, J. L. (2009). Invariance of cognitive triage in the development of recall in adulthood. Memory, 17(5), pp. 518-527. doi: 10.1080/09658210902939355

Invariance of Cognitive Triage **in the Development of Recall in Adulthood**

Tammy A. Marche [a], Mark L. Howe [b], David G. Lane [a],

Keith P. Owre [a], and Jennifer L. Briere [a]

[a] University of Saskatchewan

[b] Lancaster University

Send correspondence to:

Professor Mark L. Howe, Ph.D.

Department of Psychology

Lancaster University

Lancaster LA1 4YF

UK

E-mail: mark.howe@lancaster.ac.uk

IN PRESS: *Memory*

Abstract

Past research has demonstrated that *cognitive triage* (weak-strong-weak recall pattern) is a robust effect that optimizes children's recall. The aim of the current research was to determine whether adults' free recall also exhibits triage and whether cognitive triage is less marked with older than younger adults' recall. Younger and older adults memorized 16 unrelated words until all items were recalled perfectly. The triage pattern existed for both of the younger and older adults' recall and there was evidence for age differences in triage. Our results are consistent with claims of greater verbatim forgetting and increased susceptibility to output interference with age in adulthood. Further research is needed to determine whether fuzzy-trace theory adequately explains the aging of triage and what factors play a role in the development of this pattern of recall in adulthood.

Keywords: Cognitive triage, Adult memory development, Free recall

Invariance of Cognitive Triage in the Development of Recall in Adulthood

In most examinations of memory development, free-recall is the paradigm of choice, which is not that surprising given that this is the most common method of tapping everyday memory. A number of earlier theories (one-process accounts of recall) such as Marbe's Law (e.g., Marbe, 1901, cited in Brainerd, Reyna, & Howe, 1990) as well as contemporary theories like the association network models (e.g., Anderson & Bower, 1973), the resource hypotheses (e.g., Bjorklund & Muir, 1988), and relative strength models (e.g., Raaijmakers & Shiffrin, 1981; Wixted, Ghadisha, & Vera, 1997), predict that during free recall, stronger items will present themselves to consciousness before weaker items, and therefore, will be reported in that order. However, in studies with children and young adults, Brainerd and his colleagues (for a review, see Brainerd & Reyna, 2001) did not obtain the stronger-weaker sequence of recall but rather found a weaker-stronger-weaker order, which has been labelled the *cognitive triage effect* because of its similarity to the well-known medical procedure of treating the most difficult cases first.

Because the majority of research on cognitive triage has been performed with children, where findings indicate that triage optimizes recall (e.g., Brainerd et al., 1990), it is of great theoretical and practical importance to replicate this effect with young adults and determine whether this effect exists in older adults' recall. The aim of the present study, then, is to extend our understanding of cognitive triage by investigating the relationship between recall order and memory strength during the latter portion of the life span (i.e., from younger to older adulthood) and to determine whether this relationship varies across age. The theoretical foundation for cognitive triage, fuzzy-trace theory (FTT), is reviewed below and is followed by a description of possible developmental differences in triage during adulthood. An experiment, the first of its kind in the literature, is then described, one that examines developmental differences in triage in adults' free recall.

According to the FTT (e.g., Brainerd & Reyna, 2001), two retrieval operations are available during recall, namely, direct access of verbatim traces and reconstruction of gist traces. Verbatim traces are detailed, well-articulated representations that preserve recently encoded information whereas gist or fuzzy traces refer to schematic, degenerate representations that preserve only the gist of recently encoded information. Direct access to verbatim traces predominates at the start of output and is the more accurate of the two retrieval operations. However, verbatim memory traces are especially vulnerable to output interference that accumulates during the course of recall (Brainerd & Reyna, 2001). A greater number of targets can be output if weaker verbatim traces are recalled earlier when interference is low, followed by stronger verbatim traces, resulting in a weak (strong ordering. Once the initial verbatim traces are exhausted, recall shifts to reconstruction of gist traces in a stronger (weaker sequence. Because gist traces are not as vulnerable to output interference, as the stronger gist items are recalled, interference dissipates allowing recall of weak items in late output queues. Thus, the differential sensitivity of verbatim and gist traces to output interference leads to the overall triage (weak (strong (weak) pattern in recall by outputting items in queues where their memory traces are minimally impacted.

According to FTT, episodic activation and output interference vary systematically across a free recall test. During the course of an experiment, a network of episodic relationships becomes formed between a word's core semantic representation, contextual cues, and the core representations of the other words. Retrieving a word on a recall test produces priming of this network, known as episodic activation, which facilitates the recall of further words. The amount of activation that is released when a word is recalled depends on its memory strength. Because stronger core traces capture more episodic information than weaker core traces, words with greater memory strength release more activation. As more words are read out during the protocol, the overall level of episodic activation mounts, which aids recall of the remaining words in the target set.

However, recalling words does not uniformly facilitate recall of other words. The operations that access traces and send them on to the motor control systems to produce articulation create different types of off-task noise (Dempster, 1992, 1993; Hadley, Healy, & Murdock, 1992; Hasher

& Zacks, 1988; Howe & Rabinowitz, 1989). For example, item-specific information that has already been recalled and is therefore irrelevant to subsequent recall may be recoded into memory and compete for subsequent retrieval (Brainerd & Reyna, 1989; Hadley et al., 1992; Reyna & Brainerd, 1989). The current level of episodic activation is believed to determine the amount of output interference that a word generates when it is recalled; there is less net interference released when the network of episodic relationships is highly primed than when it is weakly primed. At the beginning of a memory test, episodic activation and output interference begin to accumulate. The episodic network will continue to be primed as words are recalled, reaching its asymptote at the end of the protocol. However, output interference should build most quickly at the beginning of a test, when episodic activation is low, reach its asymptote somewhere in the middle of a protocol, when there is ample episodic activation, and subside from then on, as the episodic network becomes totally primed. Thus, there are two points during a recall test when the interference level is low and weaker traces can be read out - namely, at the beginning of a test, before much interference has been generated, and at the end of a test, when interference is being eliminated by high episodic activation.

As study-test trials progress in a list-learning study, participants are able to form *in situ* memory strengths of items so that previously recalled items gain episodic strength in memory relative to non-recalled items (Brainerd & Reyna, 2001). At criterion, when learning is complete, the episodic relationships between items are fully established, allowing participants to make reliable discriminations between 'weak' and 'strong' items to best maximize their output through triage – indeed, this triage pattern has been found to enhance recall (Brainerd & Reyna, 2001).

With respect to developmental differences, the data are consistent with the idea that younger children's recall generates more output interference than older children's recall (e.g., Brainerd et al., 1990). According to FTT, it can be argued that deficits in performance on tasks, including dual-task paradigms (e.g., Crossley & Hiscock, 1992), can be interpreted as output interference. Developmental trends in these deficits can be explained in terms of reductions in the susceptibility to such interference experienced by older children and adults, something that should result in developmental differences in triage. At the other end of the developmental spectrum, if older adults experience more output interference than younger adults, they, like young children, will be forced to switch from weaker to stronger items earlier in the protocol. This is exactly what has been found with younger versus older children (e.g., Brainerd et al., 1990), but is yet to be examined between younger and older adults. Indeed, if older adults experience more output interference than younger adults, then age differences should be more apparent earlier in recall protocols because output interference accumulates more rapidly. Furthermore, if they experience more rapid verbatim forgetting, then they will be forced to rely on reconstruction rather than direct access earlier in the recall protocol than younger adults, something that would result in more errors, and perhaps more learning trials, for older than younger adults.

In the present study, younger and older adults memorized a list of 16 unrelated familiar words until the entire list was correctly recalled on two consecutive free recall tests. The aim of the study was to determine whether the order of recall across the entire set of items is weaker-to-stronger-to-weaker and whether there are age differences in the shape of this pattern. In particular, if older adults experience more output interference than younger adults, then they will be forced to switch from weaker to stronger items earlier in the protocol than younger adults, leaving the remaining weak words to later in the output queue when activation is highest and interference has lessened. What this means is that triage curves for older adults should have longer right than left arms than those produced by younger adults, something that is very similar to the shape of the triage curves that have been found with younger versus older children (e.g., Brainerd et al., 1990).

Method

Participants

A total of 60 younger and 60 older adults, 30 males at each age level, participated in the experiment (*M* = 21.90; SD = 3.04 and *M* = 73.72; SD = 7.19, respectively). The younger adults were undergraduate university students and the older adults were recruited primarily from local seniors' university classes and organizations. All participants reported no major health or memory problems, were living independently (i.e., without any assistance), had normal or corrected-to-normal vision, and most had some university education.

Materials and Procedure

Each participant was told that they would be shown 16 words, one at a time, and would be required to recall as many words as possible after presentation. They were also told that the goal was to recall all of the words correctly twice in a row and that they would get as many study opportunities as it took to do so. Following the description of the free recall procedure, the participant was administered the first study trial on the list of 16 nouns. The Paivio, Yuille, and Madigan (1968) norms were used to construct a list of 8 high-concrete and 8 low-concrete nouns for one-third of the participants, a list of 8 high-frequency and 8 low-frequency nouns for another third of the participants, and a list of 8 high and 8 low concrete nouns, half of which were high in frequency and half of which were low in frequency. Because there were no differences in triage among the different word lists, the data were collapsed across list type.

A study trial initially involved presenting each word, via a card (in large text), for either 2 s or 5 s for both the younger and older adults. However, the older adults found it difficult (and many of them found it impossible) to learn the list items when the items were presented at a 2 s rate; they became frustrated with the number of trials that were required to reach criterion (in some cases 10 or more trials were needed). With a 5 s presentation rate, the younger adults typically reached criterion after one or two trials. However, with a 2 s presentation rate, the number of trials required by the younger adults to reach criterion (*M* = 6.65) was much closer to the number of trials required by the older adults to reach criterion (*M* = 8.12). As criterion learning was the primary objective (cognitive triage has been found to be the most marked at criterion; Brainerd et al., 1990), different presentation rates were used to minimize age differences in ability to achieve criterion, and hence to minimize age differences in learning rate. This procedure is frequently used in developmental studies (both with children and adults) to equate task difficulty and to insure criterion learning within an optimal number of study-test cycles (e.g., see Howe, 1990). Of course, despite differences in presentation rates, the degree of learning will not differ because all participants learned to a criterion of two consecutive errorless recall trials (e.g., see Howe, 1988).

The order of word presentation on study trials was random. After 30 s of performing a filler task to prevent short-term memory and serial position effects, the individual was asked to recall as many of the words as possible, in any order he or she wished. The experimenter recorded the order in which the items were presented and recalled. The individual was administered further cycles of study/filler activity/test until the entire list was correctly recalled on two consecutive free recall tests. Once criterion was met (i.e., all items correctly recalled on two consecutive trials), all persons were debriefed and thanked for their participation.

Results

In order to compare results with those of past studies on triage, and to examine claims of greater verbatim forgetting and increased susceptibility to output interference with age, similar analyses were carried out as those reported by others (e.g., Brainerd et al., 1990). As in prior triage research, an item in a response set was classified as *strong* if it was successfully recalled on a previous trial and *weak* if it had not been recalled previously. As well, like previous research, we used two precriterion measures of recall accuracy, namely, mean total errors per trial to criterion and the mean trial number of the last error. *Mean total errors per trial* reflects the mean number of times items were not recalled on each of the previous trials, and is calculated by taking an average of the number of errors produced on each trial until criterion learning is reached. The *mean trial of last error* measure reflects the average number of trials participants needed to meet criterion, and is calculated by taking the average of the last trial number in which participants produced an error before reaching criterion.

Analyses indicated that there was a significant difference between the two age groups in the mean total errors produced per trial, $t(118) = 4.81$, $p < .001$, with the older adults producing more errors (*M* = 1.58, SD = 0.62) than the younger adults (*M* = 1.09, SD = 0.47). As well, the mean trial of last error was greater for the older adults (*M* = 2.12; SD = 0.87) than for the younger adults (*M* = 1.31, SD = 0.65), $t(118) = 5.76$, $p < .001$. Thus, recall performance was poorer for the older than the younger adults.

Of most interest was the relationship between order of recall and recall accuracy. That is, we wished to corroborate previous reports of cognitive triage, as well as determine whether triage is less marked with age. The two experimentwise measures of recall accuracy, total errors to criterion and trial number of last error, were plotted as a function of the words' positions in the output queues on the two criterion trials. In Tables 1 and 2, we report the results as Vincentized quartiles (e.g., see Levine & Burke, 1972), the measure most frequently used in triage studies.

The pattern that is indicative of the basic triage effect is a U-shaped relationship between recall accuracy (as assessed by mean total errors per trial and mean trial of last error) and output order such that words with low accuracy are recalled in the primacy and recency positions of the protocols and words with high accuracy are recalled at intermediate positions. It appears from the inspection of Tables 1 and 2 that this pattern existed at both age levels. This was statistically verified by fitting the general linear equation,

$$Y = a + bX \qquad \text{Eq. 1,}$$

and the general quadratic equation,

$$Y = a + bX + cX^2 \qquad \text{Eq. 2,}$$

to the recall accuracy/recall order plots, where Y is a word's position in the criterion recall queue, X is a measure of overall recall accuracy (e.g., total errors to criterion, trial number of last error), and a, b, and c are free parameters. If the relationship between recall accuracy and recall ordering is U-shaped, then Eq. 2 will give a better description of this relationship than Eq. 1. A total of 4 tests of this hypothesis were conducted for each of two criterion trials. Polynomial regression goodness-of-fit tests indicated that the general quadratic equation provided a better fit than the general linear equation (and the general cubic equation) for both comparisons involving the first criterion trial with both the younger and older adults ($p < .01$). The amount of variance accounted for by the quadratic fits was 91% and 93% for the younger adults and 83% and 83% for the older adults, for each of the two measures, total errors and trial of last error, respectively. Therefore, the plots of the criterion 1 data conformed to the U-shaped cognitive triage functions that have been reported in previous studies.

However, the results were slightly different with the plots of the criterion 2 data. Polynomial regression goodness-of-fit tests indicated that the general quadratic equation provided a better fit than the general linear equation (and the general cubic equation) for the total errors measure for the younger adults ($p < .01$) and for both measures for the older adults ($p < .05$). The amount of variance accounted for by the quadratic fits was 59% for the younger adults for the total errors measure, and 63% and 57% for the older adults, for each of the two measures, total errors and trial of last error, respectively. Therefore, the plots of the criterion 2 data basically conformed to the U-shaped cognitive triage functions that have been reported in previous studies, but they certainly were not as marked as they were with the criterion 1 data.

Brainerd et al. (1990) reported two developmental differences that they observed in their data. First, they found that the positions in the output queue where recall was poorest varied with age. In particular, older children's U-shaped curves were approximately symmetrical, whereas the U-shaped curves produced by younger children had longer right than left arms. They interpreted this to mean that younger children's recall generates more output interference than older children's recall. It was of interest to determine whether there was any difference between younger and older adults in the positions in the output queue where recall was poorest. If such differences existed, then they were more likely to be found with the criterion 1 data given the stronger triage patterns at criterion 1 than 2. To statistically verify whether there was an age difference in when the very weakest words were read out, 2(Quartile: first and fourth) x 4(Item) ANOVAs were carried out. A total of 4 tests (2 age levels x 2 statistics of recall) were conducted that compared recall accuracy at the first four positions against recall accuracy at the last four positions. Consistent with previous research on triage effects, the results were analyzed separately for each developmental group in order to examine the trends separately for each cohort.

The tests for both the total errors and trial of last error measures for the younger adults showed that the main effects of Item, (*F*[3, 177] = 3.70, $p < .01$, and *F*[3, 177] = 3.62, $p < .01$, respectively) and Quartile (F[1, 59] = 13.45, $p < .01$, and *F*[1, 59] = 16.72, $p < .01$, respectively) were significant, as was their interaction (*F*[3, 177] = 7.75, $p < .01$, and *F*[3, 177] = 8.73, $p < .01$, respectively). Basically performance was poorer for some of the items in the first quartile than for some of items in the last quartile. The tests for both the total errors and trial of last error measures for the older adults revealed only a Quartile x Item interaction, (*F*[3, 177] = 4.57, $p < .01$, and *F*[3, 177] = 5.57, $p < .01$, respectively). Unlike the younger adults, older adults' performance was better for some of items in the first quartile than for some of items in the last quartile. This is consistent with the idea that older adults experience too much interference initially to recall the weakest items and are forced to recall such items at the end of the protocol when episodic activation is highest. As well, the younger adults' U-shaped curves had longer left than right arms, whereas the U-shaped curves produced by older adults had longer right than left arms. This indicates that older adults experienced the build-up of interference at the beginning of the protocol more quickly than younger adults did, something that forces them to switch to the recall of stronger words much earlier than do younger adults. This accounts for the shorter left arms in the U-shaped curves of the older than younger adults. Because many of the weak items can then only be recalled at the end of the protocol when activation is high, this accounts for the longer right arms produced by the older than younger adults.

The second developmental difference noted by Brainerd et al. (1990) was that age changes in recall accuracy interacted with output position; that is, age differences in recall accuracy were smaller at the initial recall positions than at subsequent positions. To determine whether age differences in cumulative recall accuracy tended to diverge as protocols unfolded, Age x Recall position ANOVAs were conducted using either total errors to criterion or trial of last error as the performance measure. Of interest is the Age x Recall position interaction because it will be reliable if age differences in accuracy increased as recall position increased. (The Age and Recall position main effects are both trivial because we have previously found both effects to be significant.) Two such analyses of variance (for each of the two measures of recall accuracy) were conducted for the criterion 1 trial. The Age x Recall position interaction was reliable for both ANOVAs, the total errors measure, $F(15, 1770) = 1.65$, $p = .05$, indicating that age differences in recall accuracy increased with recall position, and the trial of last error measure, $F(15, 1770) = 1.71$, $p < .05$, indicating that age differences in the trial of last error increased with recall position. Therefore, these results show that older adults experience more output interference initially than younger adults and this difference becomes greater as additional items are recalled.

Discussion

Based on past research with children, triage has been demonstrated to be a rather reliable effect, one that enhances free recall (e.g., Brainerd & Reyna, 2001). The current experiment is the first to examine developmental differences in triage in adult free recall. Consistent with the previous work with children, our study has shown that for younger and older adults, both recall accuracy and recall order were nonmonotonically related; that is, the triage pattern existed in both of the younger and older adults' recall. Thus, like the findings for cognitive triage with children, when adults retrieve words under unconstrained recall conditions, they do not simply read out the stronger items first. Rather, weaker items are recalled initially, followed by stronger items, followed by the remaining weaker items.

Interestingly, the amount of variance accounted for by the quadratic fits (59% to 93% for the younger adults and 57% to 83% for the older adults) appears to be somewhat lower than has been reported with children (74% to 96% by Brainerd et al., 1990). This difference might reflect adults' greater reliance on recall strategies, strategies that might interfere with the on-line process of reporting weak words whenever output interference is low. This is consistent with the anecdotal observation, reported by some of the participants, that they constructed a story from the list items as they were initially shown and then reported the items at recall by mentally recounting the story. Although the unconscious process of noting items' error-success history could still play a major role in recall, those participants who utilize some type of conscious recall strategy would likely display a less marked triage pattern. Brainerd, Olney, and Reyna (1993) did find that selective rehearsal decreased the triage effect. In particular, the use of this strategy affected the low-priority component of triage. The fact that preadolescents spontaneously use mnemonics such as elaboration less frequently than adults (for a review, see Bjorklund & Muir, 1988), and that Brainerd et al. (1990) tested children during the optimal time for verbatim memory development, may account for what appears to be stronger triage patterns found in children's recall than those found in the present study with younger and older adults. Thus, although there is a clear invariance in cognitive triage across the lifespan, there are some interesting, although perhaps subtle, differences in the strength of these patterns, ones that may be directly related to adults' increasing reliance on the use of conscious recall strategies to support episodic memory.

As expected, recall performance was poorer for older than younger adults. Age differences in triage were also anticipated given older adults' greater susceptibility to output interference. The position in the output queue where recall was poorest varied with age and age differences increased with recall position. This is consistent with the idea that older adults experience too much interference initially to recall the weakest items and are forced to recall such items at the end of the protocol when episodic activation is highest. As well, these findings are consistent with the idea that older adults experience the build-up of interference at the beginning of the protocol more quickly than younger adults do, something that forces them to switch to the recall of stronger words much earlier than do younger adults. Therefore, the pattern of cognitive triage becomes less marked from younger to older adulthood because of the apparent increase in interference that adults experience with increasing age. Thus, our findings are consistent with prior research indicating that older adults experience greater verbatim forgetting and are more susceptible to output interference (Brainerd & Reyna, 2001). Moreover, the results are also consistent with theories that make claims concerning global processing declines with age (e.g., Dempster, 1992; 1993; Myerson, Ferraro, Hale, & Lima, 1992), as well as theories that make more specific claims, for example, of greater susceptibility to output interference, like fuzzy-trace theory. However, it is possible that age changes in cognitive triage are more a function of inhibition efficiency than resistance to interference. Given that there are developmental differences in the ability to suppress memory nodes (see Wilson & Kipp, 1998), it is possible that younger children and older adults have more difficulty both unintentionally inhibiting items that are associated with the target item as well as intentionally inhibiting previously recalled items that enter working memory, and that these deficiencies produce the triage pattern of recall. In other words, the locus of competition may not be prior to entry into working memory (as implied by FTT), but after items have entered consciousness (see the distinction between sensitivity to interference theory and inhibition efficiency theory in Wilson and Kipp, 1998).

Interestingly, the triage pattern was not as evident when the second criterion trial was used as the index of recall order. According to fuzzy-trace theory, the order of recall should be a nonmonotonic function of memory strength when either criterion trial is used as the index of recall order. With the exception of Brainerd, Reyna, Howe, and Kevershan (1991) who found a nonmonotonic relationship with the second criterion trial, results have typically not been reported for each criterion trial. One possible explanation for why there is a difference between the two criterion trials is that when assessing an item's strength, participants place more weight on their performance on the previous trial than they do on the entire error-success history of the item. Because all items may now be classified as strong or at least somewhat strong by the time of the second criterion trial, and because the high level of episodic activation would have forced the level of output interference to dissipate, it would therefore not be necessary for recall to strictly follow the weak-strong-weak pattern to achieve maximum performance.

It is interesting to note the connection between prior research on cognitive triage and current false memory research in terms of the relationship between recall of list words versus intrusions. One finding in the false memory literature is that recall of related but unpresented words (semantic intrusions) often occurs near the end of a free recall test (e.g., Payne, Elie, Blackwell, & Neuschatz, 1996). According to FTT, because recall is based on verbatim traces early in recall and gist traces later in recall, and because output interference builds with the recall of verbatim traces but gist representations are unaffected by such interference, items are generated from gist representations later in recall. Because intrusions are said to be gist-based, such falsely remembered items should occur in the latter portions of output queues when gist output is highest. Consistent with FTT's assumptions, Barnhardt, Choi, Gerkens, and Smith (2006) found that the output position of presented related words, which would be based on verbatim representations according to FTT, was earlier than the output position of nonpresented related intrusions, which would be based on gist representations. Importantly, the output positions of both types of words were closer to the middle segments of the output queues than to the ends of the recall protocols. Barnhardt et al. (2006) argued that presented related items should produce the strongest verbatim trace because those items can take advantage of both item-specific and relational processes at study. Thus, they should be the last items recalled via direct access given that recall initially follows a weak-strong pattern due to the build-up of output interference. Nonpresented related intrusions were recalled shortly after recall of the presented related items because the output order for traces reconstructed from gist is argued to proceed from the strongest to the weakest traces.

Another consistent finding in the false memory literature is that intrusion rates are not always positively correlated with the level of true recall, and in fact, some research has found a negative correlation (see Gallo, 2006). Consistent with this finding, Brainerd, Yang, Reyna, Howe, and Mills (2008) found that true and false recall loaded on different factors, with true recall loading on surface features such as imagery/concreteness and categorizability ratings of target words and false recall loading on a familiarity/meaningfulness factor. Brainerd et al. (2008) argued that their findings indicate that there are discrete representations for true and false memory at recall and provides support the output patterns found in the Payne et al. (1996) and Barnhardt et al. (2006) studies. Although output positions for true and false memories may conform to patterns derived from cognitive triage, this degree of conformity may depend on exactly how memory strength is measured (e.g., recall accuracy, number of study trials, amount of study time) (also see Jou, 2008; Rohrer & Wixted, 1994; Wixted, Ghadisha, & Vera, 1997).

Regardless of these measurement issues, the link between triage patterns and true and false recall opens up new and theoretically interesting research opportunities for better understanding memory development in both childhood and adulthood (also see Howe, 2008). Indeed, the research presented in this article establishes the existence of triage effects in both younger and older adults and serves as an important first investigation of developmental differences in these cognitive triage patterns in adult free recall. The major implication of our findings is that there is evidence of cognitive triage in adults' free recall. Despite this developmental invariance in cognitive triage across the lifespan, there are some important differences between children's triage patterns and those of adults. Indeed, this research showed that the pattern of cognitive triage is somewhat weaker in adults than children, something that may be due to (a) adults' increased reliance on conscious mnemonic strategies to enhance episodic recall or (b) increases in adults' susceptibility to interference in memory and their reduced ability to inhibit information during episodic recall.

The current research also raises a number of important questions about the nature of episodic recall in adult memory development. For example, is cognitive triage a viable explanation of developmental changes in recall throughout adulthood? That is, do these age changes we observed in cognitive triage patterns bring about the well-documented age changes that we see in recall throughout adulthood? As well, we need to determine whether, and to what degree, the spontaneous use of recall strategies interferes with the cognitive triage pattern (e.g., older adults' increased reliance on semantic processing) and whether such use produces less marked triage patterns with adults (who are considerably more proficient in strategy use) than with children (who are only beginning to learn how to implement strategic processes). Because it has been shown that cognitive triage can enhance recall, it may be that the use of more intentional strategies could impede this more "automatic" form of free recall (Howe, 2008). This calls into question the central assumption of the mnemonic approach to memory development inasmuch as the efficient use of conscious mnemonic strategies may not serve to optimize recall (Harnishfeger & Brainerd, 1994), but rather, act to interfere with an already effective cognitive triage mechanism. Alternatively, these more sophisticated mnemonic strategies might produce better recall in more trying memory circumstances than the ones used in triage research (e.g., prospective remembering), something that is important if we are to have a complete theory of memory development across the lifespan. Through a better understanding of the nature of triage, we will gain insight into the more automatic as well as the more conscious components that constitute lifespan changes in memory, and in the end, have a more comprehensive theory of the key changes that constitute memory development in both childhood and adulthood.

References

Anderson, J. R., & Bower, G. H. (1973). *Human associative memory*. Washington, DC: Winston.

Barnhardt, T. M., Choi, H., Gerkens, D. R., & Smith, S. M. (2006). Output position and word relatedness in a DRM paradigm: Support for a dual-retrieval process theory of free recall and false memories. *Journal of Memory and Language, 55*, 213-231.

Bjorklund, D. F., & Muir, J. E. (1988). Children's development of free recall memory: Remembering on their own. *Annals of Child Development, 5*, 79-123.

Brainerd, C. J., Olney, C. A., & Reyna, V. F. (1993). Optimization versus effortful processing in children's cognitive triage: Criticism, reanalysis, and new data. *Journal of Experimental Child Psychology, 55*, 353-373.

Brainerd, C. J., & Reyna, V. F. (2001). Fuzzy-trace theory: Dual processes in memory, reasoning, and cognitive neuroscience. *Advances in Child Development and Behavior, 28*, 41-100.

Brainerd, C. J., Reyna, V., F., & Howe, M. L. (1990). Cognitive triage in children's memory: Optimal retrieval or effortful processing? *Journal of Experimental Child Psychology, 49*, 428-447.

Brainerd, C. J., Reyna, V. F., Howe, M. L., & Kevershan, J. (1991). Fuzzy-trace theory and cognitive triage in memory development. *Developmental Psychology, 27*, 351-369.

Brainerd, C. J., Yang, C., Reyna, V. F., Howe, M. L., & Mills, B. A. (2008). Semantic processing in "associative" false memory. *Psychonomic Bulletin & Review, 15*, 1035-1053.

Crossley, M., & Hiscock, M. (1992). Age-related differences in concurrent-task performance of normal adults: Evidence for a decline in processing resources. *Psychology and Aging, 7*, 499-506.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*, 45-75.

Dempster, F. N. (1993). Resistance to interference: Developmental changes in a basic processing mechanism. In M. L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development: Vol. 1. Foundations* (pp. 3-27). New York: Springer-Verlag.

Gallo, D. G. (2006). *Associative illusions of memory: False memory research in DRM and related tasks.* New York: Psychology Press.

Hadley, J. A., Healy, A. F., & Murdock, B. B. (1992). Output and retrieval interference in the missing-number task. *Memory & Cognition. 20*, 69-82.

Hartley, A. A. (1993). Evidence for the selective preservation of spatial selective attention in old age. *Psychology and Aging, 6*, 587-594.

Harnishfeger, K. K., & Brainerd, C. J. (1994). Nonstrategic facilitation of children's recall: Evidence of triage with semantically related information. *Journal of Experimental Child Psychology, 57*, 259-280.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 193-225). New York: Academic Press.

Howe, M. L. (1988). Measuring memory development in adulthood: A model-based approach to disentangling storage-retrieval contributions. In M. L Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood* (pp. 39-64). New York: Springer-Verlag.

Howe, M. L. (1990). Development of a mathematical model of memory for clinical research applications in aging. In M. L. Howe, M. J. Stones, & C. J. Brainerd (Eds.), *Cognitive and behavioral performance factors in atypical aging* (pp. 3-36). New York: Springer-Verlag.

Howe, M. L. (2008). What is false memory development the development of? Comment on Brainerd, Reyna, and Ceci (2008). *Psychological Bulletin, 134*, 768-772.

Howe, M. L., & Rabinowitz, F. M. (1989). On the uninterpretibility of dual-task performance. *Journal of* Experimental Child Psychology, 47, 32-38.

Jou, J. (2008). Recall latencies, confidence, and output positions of true and false memories: Implications for recall and metamemory theories. *Journal of Memory and Language, 58*, 1049-1064.

Levine, G., & Burke, C. J. (1972). *Mathematical model techniques for learning theories*. New York: Academic Press.

Myerson, J., Ferraro, F. R., Hale, S., & Lima, S. D., (1992). General slowing in semantic priming and
word recognition. *Psychology and Aging, 7,* 257-270.
Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for
925 nouns. *Journal of Experimental Psychology Monographs, 76* (1, Pt.2).
Payne, D. G., Elie, C. J., Blackwell, J. M., & Neuschatz, J. S. (1996). Memory illusions: Recalling,
recognizing, and recollecting events that never occurred. *Journal of Memory and Language, 35,*
261-285.
Raaijmakers, J. G., & Shiffrin, R. M. (1981). SAM: Search of associative memory.
Psychological Review, 88, 93-134.
Rohrer, D., & Wixted, J. T. (1994). An analysis of latency and interresponse time in free recall. *Memory*
& Cognition, 22, 511-524.
Tun, P. A., Wingfield, A., Rosen, M. J., & Blanchard, L. (1998). Response latencies for false memories:
Gist-based processes in normal aging. *Psychology and Aging, 13,* 230-241.
Wilson, S. P. & Kipp, K. (1998). The development of efficient inhibition: Evidence from directed-forgetting tasks. *Developmental Review, 18,* 86-123.
Wixted, J.T., Ghadisha, H. & Vera, R. (1997). Recall latency following pure- and mixed-strength lists: A direct test of the relative strength model of free recall. *Journal of Experimental Psychology: Learning, Memory and Cognition, 23,* 523-538.

Table 1

Means (and Standard Deviations) for the Relationship Between Recall Order and Recall Accuracy for Criterion 1

Age/Measure	Recall Order (Vincentized quartiles) 1	2	3	4
Younger				
Mean Total Errors	1.48 (1.17)	0.97 (1.05)	0.86 (0.87)	1.05 (1.04)
Mean Last Error	1.88 (1.56)	1.09 (1.26)	1.01 (1.11)	1.25 (1.31)
Older				
Mean Total Errors	1.70 (1.53)	1.35 (1.30)	1.42 (1.22)	1.85 (1.44)
Mean Last Error	2.30 (2.12)	1.83 (1.82)	1.81 (1.65)	2.52 (2.03)

Table 2

Means (and Standard Deviations) for the Relationship Between Recall Order and Recall Accuracy for Criterion 2

	Recall Order (Vincentized quartiles)			
Age/Measure	1	2	3	4
Younger				
Mean Total Errors	1.22 (1.20)	0.96 (0.99)	1.06 (0.91)	1.13 (1.17)
Mean Last Error	1.51 (1.56)	1.15 (1.27)	1.22 (1.14)	1.35 (1.46)
Older				
Mean Total Errors	1.62 (1.47)	1.41 (1.22)	1.45 (1.37)	1.84 (1.47)
Mean Last Error	2.19 (1.90)	1.89 (1.69)	1.91 (1.83)	2.47 (1.95)