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The Allure of the Alignable: Younger and Older Adults' False Memories of Choice Features

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When making choices, people often try to directly compare the features of different options rather than evaluating each option separately. Not every feature has an analogous (or alignable) feature in the other option, however. In this study, both younger and older adults filled in such gaps when remembering, creating features in the other option to contrast with existing features. Thus, participants had a tendency to remember choice options as more comparable than they originally were. High performance on tasks tapping strategic processing was associated with a pattern of mostly feature-based comparisons during choice for older adults but with a pattern of mostly option-based comparisons for younger adults. This pattern suggests that younger and older adults' comparison processes are influenced by different goals.

Imagine choosing between two vacation apartments in another country. The listings indicate the rent for both apartments but provide interior photographs for only one of the options. Thus, direct comparison of the options is easier by price than by attractiveness. As illustrated by this example, there is not always enough information to compare choice options directly on every relevant feature. In this study, we examine whether comparing choice options that possess nonalignable features leads to false memories that make the choice options more comparable. In addition, we examine whether comparison processes and their impact on later memory change with age.

Strategies During Choice

In the process of making a choice, there are a number of possible strategies for comparing all of the option features. For instance, the weighted additive strategy involves considering one option at a time. Each feature value (e.g., Apartment A's value for location) is multiplied by the importance weight for that type of feature, and then all of the weighted values are summed to compute an overall value for that alternative (Keeney & Raiffa, 1976). The alternative with the highest value should be chosen.

Other, often simpler strategies involve comparisons of features across options. One example is choosing the option with the best value on the most important feature (Tversky, 1969). That is, one might take the apartment with the lowest rent, regardless of its attractiveness or location. Another feature-based strategy is to eliminate options that do not meet a cut-off value for the most important feature, then eliminate those that do not meet the cut-off for the second most important feature, and so on until one is left with only one option (Tversky, 1972). The common characteristic of feature-based strategies is that people compare features across options to evaluate the options.

Alignability

When making a choice or a similarity judgment, people often use feature-based strategies in which they attempt to place elements of one item in correspondence with elements from the other. This alignment process yields commonalities, alignable differences, and nonalignable differences (e.g., Medin, Goldstone, & Gentner, 1993; Medin, Goldstone, & Markman, 1995). Features of options that differ from each other but can nevertheless be placed in correspondence, such as the rent for the two apartments, are alignable differences. In contrast, nonalignable differences arise when there is a feature in one option that has no corresponding feature in the other options, such as the attractiveness of the two apartment options described above.

Attention is directed toward dimensions of the items that can be compared, leading the alignable elements to be weighted more heavily than the nonalignable elements in similarity judgments (e.g., Markman & Gentner, 1996; but see Estes & Hasson, 2004) or choices (Markman & Medin, 1995; Nowlis & Simonson, 1997; Slovic & MacPhillamy, 1974). For example, when given a choice between two brands of popcorn, participants were more likely to choose the one with superior alignable differences, such as "pops in its own bag" compared with "requires a microwave bowl," than the one with superior nonalignable differences, such as "not likely to burn" compared with "has some citric acid" (Zhang & Markman, 2001).

Alignability and Memory

This comparison process also influences later memory. Markman and Gentner (1997) showed participants two pictures that

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contained both alignable and nonalignable differences. For example, a pig in one picture was alignable with a baby in another picture, because both were making a mess. A helicopter flying overhead in one picture was not in correspondence with anything in the other picture and so was a nonalignable difference. Later, participants were provided with one of the features from the pictures and were asked to recall everything they remembered from the pictures. When provided with an alignable feature from the pictures, participants remembered more information about the pictures than when provided with a nonalignable feature as a cue.

In addition to serving as better cues for other aspects of a situation, alignable features are more likely to be recalled than nonalignable features (Zhang & Markman, 1998, 2001). For instance, participants who evaluated descriptions of three brands of popcorn later were more likely to remember alignable features (e.g., "small-size kernels," "medium-size kernels," and "very large kernels") than nonalignable features (e.g., "easy to swallow," "not tough," and "pops in its own bag").

This enhanced memory for alignable features may be the result of selective attention during the comparison process (Markman & Gentner, 1997). That is, when making comparisons, people may spend more time considering the alignable features than the other types of features. However, better encoding is not the only factor that could make alignable features more memorable. Like other cognitive strategies, such as categorization and the use of schemas, alignment processes may lead to biases in memory favoring alignable features. When choosing or retrieving information about the choice options, people may infer new features to fill in gaps where the options were not directly comparable. Previous research has not examined whether alignment processes lead to false alignable memories. In Zhang and Markman's (1998, 2001) studies, errors in recall were not examined. In Markman and Gentner's (1997) study, retrieval cues were either alignable features or nonalignable features, but there was no comparison of whether alignable or nonalignable features were more likely to be recalled.

Aging and Alignability

One of the most notable changes in memory with age is the decline seen in *strategic processes*—that is, self-initiated encoding and retrieval processes such as planning, organizing, or noting relations (M. K. Johnson & Raye, 2000). For example, older adults are less likely than younger adults to generate novel connections or organizational schemes that help later retrieval of information (Hultsch, 1969). This decline in strategic processes appears to be due to age-related deterioration of frontal brain regions (M. K. Johnson & Raye, 2000; Prull, Gabrieli, & Bunge, 2000; Zacks, Hasher, & Li, 2000).

How might older adults' reductions in strategic processing affect alignment processes? One possibility suggested in several reviews of aging and decision making (Peters, Finucane, MacGregor, & Slovic, 2000; Sanfey & Hastie, 2000; Yates & Patalano, 1999) is that comparing options across features requires less cognitive load than do alternative-based strategies such as the weighted additive approach, in which information is evaluated, weighted, and averaged for each alternative. Prefrontal brain regions play a key role in working memory capacity, so, from this perspective, older adults with decline in prefrontal regions should engage in more feature-based and fewer alternative-based comparisons than younger adults. Thus, when faced with various features of a choice, older adults may be more likely to attempt to align them across options, leading their memories to include more gap-filling new features than younger adults' memories.

The possibility that aging is associated with increases in feature-based comparisons is supported by one study in which older adults used more feature-based search strategies when choosing (M. M. S. Johnson, 1990). However, this age difference did not replicate in subsequent studies, so the existing evidence about age differences in comparison strategies is ambiguous (Hartley, 1990; M. M. S. Johnson, 1993, 1997).

Another relevant age difference is the finding that older adults focus more on emotion regulation than do younger adults (for a review see Carstensen, Isaacowitz, & Charles, 1999). Among younger adults, increasing the need for emotion regulation in a choice increases the degree to which their strategies are feature based rather than alternative based (Luce, Bettman, & Payne, 1997). Feature-based strategies can help reduce decision conflict because they do not involve making trade-offs of positive and negative features within one option (Hogarth, 1987). Thus, this perspective makes a different prediction than the one focusing on working memory capacity: Older adults may make more feature-based comparisons to help reduce the negative affect associated with decision conflict, which may, in turn, make alignable features more memorable.

Older adults' increased focus on emotional goals does seem to influence their memories (Charles, Mather, & Carstensen, 2003; Kennedy, Mather, & Carstensen, 2004; Mather & Johnson, 2000). In particular, older adults seem to remember more emotionally positive information, relative to negative information, than do younger adults (for reviews, see Knight & Mather, in press; Mather, 2004). To follow up on these findings, in the present study we examine whether there are age differences in memory for positive and negative information from the choice options. In addition, in the decision search task we examine whether there are age differences in how much time participants spent examining positive or negative features when making choices.

Overview of Experiments

In the following experiments, we first test our hypothesis that, in addition to improving memory for alignable features as demonstrated in previous studies (Zhang & Markman, 1998, 2001), alignment processes lead to false memories. In particular, choice options with some missing information should be associated with alignable false memories. For example, if the first apartment option lists hardwood floors as a feature and the second does not mention flooring type, one might later fill in the missing information by incorrectly remembering that the second apartment had wall-to-wall carpeting rather than hardwood floors. In Experiment 1 we test recognition memory accuracy for option features, and in Experiment 2 we test recall accuracy. In both of these experiments, we also examine how the passage of time interacts with alignability.

We then test whether alignment processes have more or less of an impact on older adults than younger adults using a recognition memory test in Experiment 3. In Experiment 4A, participants completed a recall memory test for the choice options and several strategic memory tasks. We examine whether individual differences in strategic processing abilities predict use of structural alignment processes. Finally, a decision search task in Experiment 4B allows us to see whether prior findings of increased feature-based search strategies among older adults (M. M. S. Johnson, 1990) replicate, and, if so, if they are related to individual differences in strategic processing.

Experiment 1

We examined the impact of alignability on both correct and false recognition as well as on source-monitoring accuracy by giving participants a hypothetical choice between two options and then a source attribution memory test. For each option, half the features were alignable with features in the other option (e.g., for one college, "mediocre teaching," and for the other, "award-winning teaching"). The remaining features were not alignable. For these nonalignable features, there was information about that dimension for one of the options but not for the other option (e.g., for one college, "alumni do not usually maintain close ties with the school," whereas, for the other college, the quality of the alumni connections was not mentioned).

After a delay, we gave participants a memory test that included both old features (half of the alignable and half of the nonalignable features from the options) and new features. Half of these new features were alignable with an old feature that had not been aligned in the choice scenario (e.g., "strong alumni network"), whereas the other half corresponded with dimensions that had not been mentioned for either option. As shown in Table 1, choice features were counterbalanced across participants so that each feature occurred equally often as each type of item. We expected both hits (correctly recognized old items) and false alarms (incorrectly recognized new items) to be greater for alignable features than for nonalignable features. Of particular interest was whether

Table 1
Choice Option Features Used in Experiments 1 and 2

Option A	Option B
Counterbalancing Version 1	
Mediocre teaching	Friendly atmosphere on campus
Many exciting things to do off campus	High number of students per faculty member
Dorm rooms tend to be spacious	Most dorm rooms look cramped
Unattractive campus	Has a large number of different majors available
People on campus do not seem sociable	Top-ranked athletic programs
Great theater and arts programs	Financial aid program is only average
Low number of students per faculty member	Dorm food is not great
Not much available in the campus bookstore	Beautiful campus
Counterbalancing Version 2	
The choice of majors is somewhat limited	Extensive selection in campus bookstore
Food service has won awards	Isolated campus with little to do nearby
Great theater and arts programs	Not well known for its theater and arts programs
Mediocre teaching	Great weather
Not much available in the campus bookstore	Low tuition
Great financial aid program	Alumni do not usually maintain close ties with the school
Many exciting things to do off campus	Reputation is above average, but not great
Athletic programs are weak	Award-winning teaching
Counterbalancing Version 3	
Unpleasant weather	Top-ranked athletic programs
Great reputation	Financial aid program is only average
Food service has won awards	Dorm food is not great
The choice of majors is somewhat limited	Beautiful campus
Athletic programs are weak	Friendly atmosphere on campus
Strong alumni network	High number of students per faculty member
Great financial aid program	Most dorm rooms look cramped
High tuition	Has a large number of different majors available
Counterbalancing Version 4	
Unattractive campus	Low tuition
Dorm rooms tend to be spacious	Alumni do not usually maintain close ties with the school
Great reputation	Reputation is above average, but not great
Unpleasant weather	Award-winning teaching
High tuition	Extensive selection in campus bookstore
Low number of students per faculty member	Isolated campus with little to do nearby
Strong alumni network	Not well known for its theater and arts programs
People on campus do not seem sociable	Great weather

people were better able to discriminate old and new alignable or nonalignable items. We also examined whether the impact of alignability changes as time passes. Participants were given the memory test either immediately, 1 day, or 1 week after making the choice.

Method

Participants. Forty-eight undergraduates at the University of California, Santa Cruz, completed the study. Thirty additional participants were excluded from the study because they did not complete the follow-up (see exclusion criteria in *Procedure* section). Equal numbers of participants received each of the four counterbalancing versions.

Materials. We created a choice between two colleges in which four of the features for each option were alignable with features from the other option and the other four of the features for each option were nonalignable. To counterbalance which features were alignable and which were not, we used four versions of the choice scenario, with 16 pairs of alignable features across these versions (see Table 1). Each pair included one negative and one positive feature (e.g., "high tuition" and "low tuition"). Each feature appeared as an alignable feature in one version and as a nonalignable feature in another version of the choice scenario. The option features were listed in random order, so that the four alignable features were not usually in the same location in the list as their corresponding features in the other option.

The memory test list consisted of one feature from each of the 16 pairs of features, with features from each option equally represented (see Table 2). The same test list was used for all participants. For each participant, there were eight old features (four aligned, and four nonaligned) and eight new features (four were alignable with old features, and four were not alignable with any old features). Half of the items of each type were positive, and half were negative. Next to each feature was a set of parentheses; participants were asked to indicate by writing (in the no-delay condition) or typing (in the other two conditions) within the parentheses which option the feature had been associated with (A or B) or whether it was new (X).

Procedure. Participants were invited to participate in the study as they left campus dining halls. They were told they could earn $2 by participating and were informed that participation required about 5 min of their time at that moment and that they would have to answer a questionnaire that would be e-mailed to them within a week (they were not told it would be a memory test). They were randomly assigned to either a no-delay, a 1-day-delay, or a 1-week-delay group. Participants filled out a consent form and completed the choice. Then they were thanked and reminded that they would be e-mailed with a follow-up questionnaire within a week, unless they were in the no-delay condition, in which case they were asked to complete the questionnaire right then. Participants in the 1-day-delay group were e-mailed about 18 hr after they completed their choices and received a telephone reminder 8 hr later if they had not yet responded. If no response was received within 30 hr of the choice, participants were not included in the study. Members of the 1-week-delay group were e-mailed approximately 138 hr (6 days) after they completed the choice, with a telephone reminder 32 hr later. If they still had not responded 54 hr after the e-mail was sent, they were not included in the study.

Results

For all of the analyses in this article, we used a .05 alpha level, included 95% confidence intervals, and used partial eta squared (η_p^2) to measure effect size.

Hits. We analyzed the proportion of old features that were correctly identified as having been in the choice scenario using a 2 (alignable in scenario: yes, no) × 3 (delay: none, 1 day, 1 week) analysis of variance (ANOVA; see Table 3 for means). The only significant effect was an interaction of whether features were alignable and delay, $F(2, 45) = 7.31$, $MSE = 0.01$, $p < .01$, $\eta_p^2 = .25$. After a week, alignable features were more often correctly recognized ($M = 0.92 \pm 0.07$) than nonalignable features ($M = 0.78 \pm 0.07$). In contrast, after a day, alignable and nonalignable features were equally often recognized ($M = 0.95 \pm 0.07$ vs. $M = 0.95 \pm 0.07$), and immediately after the choice, alignable features were less often correctly recognized ($M = 0.86 \pm 0.07$) than nonalignable features ($M = 0.94 \pm 0.07$).

False alarms. We used a 2 (alignable with old items: yes, no) × 3 (delay: none, 1 day, 1 week) ANOVA to analyze the proportion of new items on the test that were incorrectly attributed to one of the choice options (see Table 3 for means). There was a main effect of alignability with old items, $F(1, 45) = 37.00$, $MSE = 0.04$, $p < .001$, $\eta_p^2 = .45$, with more false alarms to alignable new items ($M = 0.40 \pm 0.08$) than to nonalignable new items ($M = 0.15 \pm 0.06$), as predicted. There was also a main effect of delay, $F(1, 45) = 13.95$, $MSE = 0.06$, $p < .001$, $\eta_p^2 = .38$. The proportion of new features incorrectly recognized increased with time ($M = 0.11 \pm 0.09$; $M = 0.29 \pm 0.09$; $M = 0.43 \pm 0.09$, for no-delay, 1-day-delay, and 1-week-delay conditions, respectively). There was not a significant interaction of alignability and delay, $F(2, 45) = 0.54$, $\eta_p^2 = .03$.

Recognition accuracy. We calculated d' separately for alignable and nonalignable items (see Table 3 for means). A 2 (alignability: alignable, nonalignable) × 3 (delay: none, 1 day, 1 week) ANOVA revealed a main effect of alignability, $F(1, 45) = 20.69$, $MSE = 0.56$, $p < .001$, $\eta_p^2 = .32$. Participants were less able to discriminate old alignable items ($M = 1.53 \pm 0.24$) from new alignable items than to discriminate old nonalignable items from new nonalignable items ($M = 2.23 \pm 0.22$). It is not surprising that

Table 2
Memory Test Items and the Item Type Category They Were in for Counterbalancing Version 1

Item types for Version 1	Items[a]
Alignable old features	Low number of students per faculty member
	Most dorm rooms look cramped
	People on campus do not seem sociable
	Beautiful campus
Nonalignable old features	Dorm food is not great
	Not much available in the campus bookstore
	Many exciting things to do off campus
	Has a large number of different majors available
Alignable new features	Not well known for its theater and arts programs
	Athletic programs are weak
	Great financial aid program
	Award-winning teaching
Nonalignable new features	Great weather
	Reputation is above average, but not great
	Strong alumni network
	High tuition

[a] These were randomly ordered on the test.

Table 3
Recognition and Source Attribution Accuracy for Alignable and Nonalignable Choice Option Features in Experiment 1

	Alignable features						Nonalignable features					
	No delay		Day delay		Week delay		No delay		Day delay		Week delay	
Accuracy measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Hits	.86	.04	.95	.04	.92	.04	.94	.04	.95	.04	.78	.04
False alarms	.20	.07	.44	.07	.56	.07	.02	.05	.14	.05	.30	.05
d′	1.94	0.20	1.57	0.20	1.09	0.20	2.81	0.19	2.46	0.19	1.41	0.19
C	−.09	.12	−.59	.12	−.73	.12	.07	.09	−.14	.09	−.11	.09
Source accuracy	.98	.06	.89	.06	.60	.06	.93	.06	.79	.06	.72	.06

there also was a main effect of delay, with recognition accuracy declining as time passed, $F(1, 45) = 16.06$, $MSE = 0.66$, $p < .001$, $\eta_p^2 = .42$ ($M = 2.38 \pm 0.29$; $M = 2.01 \pm 0.29$; $M = 1.25 \pm 0.29$, for no-delay, 1-day-delay, and 1-week-delay conditions, respectively). Alignability and delay did not interact significantly, $F(2, 45) = 1.47$, $\eta_p^2 = .06$. Thus, relative accuracy for alignable and nonalignable features did not change over time.

Response bias. We used *C* to measure participants' response bias to identify features as old (Macmillan & Creelman, 1991, p. 33). Values of *C* above zero indicate a conservative bias (less willingness to call features old), and values below zero indicate a liberal bias. A 2 (alignability: alignable, nonalignable) × 3 (delay: none, 1 day, 1 week) ANOVA revealed a main effect of alignability, indicating that participants were more biased to identify alignable features as old ($M = -0.47 \pm 0.14$) than to identify nonalignable features as old ($M = -0.06 \pm 0.10$), $F(1, 45) = 36.54$, $MSE = 0.11$, $p < .001$, $\eta_p^2 = .45$. A main effect of delay indicated that response biases became more liberal with time, $F(1, 45) = 6.75$, $MSE = 0.24$, $p < .01$, $\eta_p^2 = .23$ ($M = -0.01 \pm 0.17$ for no delay; $M = -0.37 \pm 0.17$ for 1-day delay; $M = -0.42 \pm 0.17$ for 1-week delay). Particularly interesting, however, was the interaction of alignability and delay, $F(1, 45) = 3.84$, $MSE = 0.11$, $p < .05$, $\eta_p^2 = .15$. Although response biases became more liberal over time for both alignable and nonalignable features, this trend was larger for alignable features than for nonalignable features (see Table 3).

Source accuracy. A 2 (aligned in choice scenario: yes, no) × 3 (delay: none, 1 day, 1 week) ANOVA on the proportion of correctly recognized old items that were correctly attributed to the option they had been associated with did not reveal any effects of alignability. Thus, whether items were alignable did not affect how accurately participants remembered which option they were associated with (see Table 3), $F(2, 45) = 0.05$, $\eta_p^2 = .00$, and alignability did not significantly interact with delay, $F(2, 45) = 1.77$, $p = .18$, $\eta_p^2 = .07$. It was not surprising, however, that source attribution accuracy decreased over time ($M = 0.96 \pm 0.07$ for no delay, $M = 0.84 \pm 0.08$ for 1-day delay, and $M = 0.66 \pm 0.08$ for 1-week delay), $F(2, 45) = 14.46$, $MSE = 0.05$, $p < .001$, $\eta_p^2 = .39$.

Source attributions of alignable new features. It is possible that participants' false recognition of alignable features resulted only from similarity rather than from alignability. Some of the alignable pairs share words (e.g., "unpleasant weather" and "great weather"), and all of them share concepts. Having seen "unpleasant weather," one might be more likely to falsely recognize "great weather" simply because of a memory of something about the weather. If false recognition of alignable features is driven by the similarity of each alignable new feature to its previously seen pair, then participants should be more likely to attribute the new feature "great weather" to the option that "unpleasant weather" was associated with than to the other option. In contrast, if structural alignment processes cause the false recognition, then participants should be more likely to attribute "great weather" to the option that was not associated with "unpleasant weather."

In fact, a higher proportion of the alignable new features were attributed to the alignable source ($M = 0.27 \pm 0.06$) than to the similar source ($M = 0.13 \pm 0.05$), $F(1, 45) = 9.06$, $MSE = 0.04$, $p < .005$, $\eta_p^2 = .17$, which indicates that alignability played a larger role in creating these false memories than similarity did. In contrast, there was no significant difference in the bias to attribute these features to one source or the other when they were presented as nonalignable features at test, $F(1, 45) = 0.68$, $MSE = 0.02$, $p = .41$, $\eta_p^2 = .02$.

Discussion

Experiment 1 demonstrates that the memory processes associated with alignability do not always lead to better accuracy. Participants had a more liberal response criterion for alignable features, which indicates that they were more likely to call them old than nonalignable features. Furthermore, recognition accuracy was lower for alignable than for nonalignable features. As expected, participants forgot the features of the decision over time. It is notable, however, that there was no interaction between delay and alignability on overall recognition accuracy. Thus, the influence of alignment processes on recognition accuracy for option features did not change as time passed. In contrast, response biases increased more over time for alignable than for nonalignable features.

Experiment 2

Instead of the recognition test from Experiment 1, in this experiment we used a recall test. It is possible that the relatively high level of false alarms to alignable features found in Experiment 1 is a phenomenon that is unique to recognition memory, which, unlike free recall, does not require self-initiated processing. In addition, using a recall test allowed us to examine whether false memories of alignable features tend to occur in tandem with correct memories of their feature pair (e.g., those who incorrectly remember "great weather" also correctly remember "unpleasant weather"). Other than the memory test, all aspects of the study were the same as in Experiment 1.

Method

Participants. Forty-eight undergraduates at the University of California, Santa Cruz, completed the study. An additional 22 participants filled out the choice sheet but did not complete the follow-up within the required time. As in the previous experiment, equal numbers of participants received each of the four counterbalancing versions.

Materials. The choice scenario was identical to the one used in Experiment 1. The memory questionnaire had separate headers for College A and College B. We asked participants to list all the features they could remember from the choice options, listing each one under the college label it was previously associated with.

Procedure. The procedure was the same as in Experiment 1, except that the recall test was substituted for the source attribution test.

Coding. Each recalled feature was matched with 1 of the 32 features in the stimulus set or identified as not from the stimulus set. For a recalled feature to be considered a match with a stimulus item, it had to convey the same meaning or have the same gist. One coder coded all of the data, and an additional two coders each coded half of the data. Coders were blind to condition, so they did not know which of the features each participant had seen. Interrater reliability was 97%, and discrepancies were resolved through discussion. Coders were able to match almost all recalled features with stimulus items, even when the matched stimulus item had not been seen by that participant (e.g., a participant remembered one college as having "friendly people," even though the version had not included the features about sociability or friendliness). Two percent of the features recalled (11 features across all the participants) could not be matched to any stimulus features and are not included in the following analyses.

Results

Correct recall. We analyzed the number of old features correctly identified as having been in the choice scenario using a 2 (alignable in choice scenario: yes, no) × 3 (delay: none, 1 day, 1 week) ANOVA. On average, participants recalled more alignable features ($M = 4.46 \pm 0.50$) than nonalignable features ($M = 3.08 \pm 0.39$), $F(1, 45) = 20.78$, $MSE = 2.34$, $p < .001$, $\eta_p^2 = .31$. In addition, the average total number of features accurately recalled decreased over time, $F(1, 45) = 5.78$, $p < .01$, $\eta_p^2 = .20$ (see Table 4).

False recall. We used a 2 (alignable with old items: yes, no) × 3 (delay: none, 1 day, 1 week) ANOVA to analyze the number of features incorrectly recalled as part of the choice scenario. Participants' false recall included more features alignable with previously seen features ($M = 1.08 \pm 0.26$) than features not alignable with previously seen features ($M = 0.21 \pm 0.14$), $F(1, 45) = 37.91$, $MSE = 0.49$, $p < .001$, $\eta_p^2 = .46$. In addition, false recall increased over time, $F(1, 45) = 4.30$, $p < .05$, $\eta_p^2 = .16$ (see Table 4).

False recall with matching old feature. As in the previous experiment, we were interested in whether the false memories of alignable features were simply overgeneralized memories, in which, for example, people remember that something was said about how attractive the campus was but do not remember whether the campus was attractive or unattractive. Thus, among the 33 participants who falsely recalled at least one alignable new feature, we computed the proportion of falsely recalled alignable features that were recalled together with the old feature they corresponded with ($M = 0.71 \pm 0.14$). Recalling both the alignable new feature and the old feature it corresponds with rules out the possibility that the false recall is a simple distortion or overgeneralization of an old feature. Instead, it indicates that participants created an additional feature to correspond with the one they remembered from the choice scenario. The proportion of false recall occurring as part of an alignable pair of features did not increase significantly over the delay, $F(1, 32) = 1.11$, $\eta_p^2 = .07$.

We also examined recall of previously nonaligned old features to see how often these features were recalled with a new, matching feature. Across the three delay conditions, 30% (± 0.09%) of the old nonalignable features were made into alignable features during memory retrieval by the additional false recall of a matching feature. This proportion increased with the delay, $F(2, 44) = 3.97$, $MSE = 0.10$, $p < .05$, $\eta_p^2 = .15$ ($M = 0.15 \pm 0.16$ for no delay; $M = 0.27 \pm 0.16$ for 1-day delay; $M = 0.47 \pm 0.16$ for 1-week delay).

Discussion

As was found by Zhang and Markman (Zhang & Markman, 1998, 2001), alignable features were more frequently correctly recalled than nonalignable features. However, we also found an effect of alignability on false recall. Participants falsely remembered more new features that were alignable with previously seen features than those that were not. In addition, as was found for overall recognition accuracy in Experiment 1, there was no interaction of delay and alignability for accurate recall. However, over time, nonalignable old features were more likely to be recalled together with new matching features, which made them alignable. In fact, after a week, nearly half of all correctly recalled nonalignable old features were recalled together with a new, matching

Table 4
Average Number of Features Recalled for Alignable and Nonalignable Choice Option Features in Experiment 2

	Alignable features						Nonalignable features					
	No delay		Day delay		Week delay		No delay		Day delay		Week delay	
Recall type	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Correct	5.44	0.43	4.31	0.43	3.63	0.43	3.63	0.33	2.75	0.33	2.88	0.33
False	0.75	0.22	1.00	0.22	1.50	0.22	0.06	0.12	0.19	0.12	0.38	0.12

feature. This increase over time in the bias to distort memory so that features become alignable is consistent with the increase over time in the bias to identify alignable new features as old in Experiment 1.

Experiment 3

The results from the first two experiments suggest that, when remembering choice options that had some alignable features, younger adults often create new features to fill in gaps where features could not be directly compared. In Experiments 3 and 4A, we examine whether older adults show as much of a memory bias favoring alignable features as younger adults do. For these experiments, we developed two new choices (between apartments and between health plans). As in the previous experiments, the option features were counterbalanced so that every feature appeared equally often as each type of item. As in Experiment 1, participants made the choices and later completed a source attribution test for features.

Method

Participants. Forty younger adults ($M = 23.65$ years, $SD = 3.10$) and 40 older adults ($M = 72.50$, $SD = 5.00$) participated (both groups lived in the community). Vocabulary scores from the Wechsler Adult Intelligence Scale—Revised (WAIS–R; Wechsler, 1981) were lower for the younger ($M = 44.20$, $SD = 12.50$) than for the older groups ($M = 50.40$, $SD = 11.00$), $t(77) = 2.33$, $p < .05$.

Materials. Apartment and health plan choices were constructed according to the same format as the college choice in Experiment 1. As in the previous experiments, which features were alignable was counterbalanced across participants for four versions of the choice scenarios. Memory tests corresponding with each choice scenario also used the same structure as that in Experiment 1.

Procedure. The health plan choice was presented on the first page of a questionnaire booklet, followed by the apartment choice on the next page. After making the choices, participants were given a list of words from the WAIS–R and asked to write definitions for each one (typically a 10-min task). Then participants completed the memory test for the health plan choice, followed by the memory test for the apartment choice on a separate page.

Results

We collapsed across scenario in the following analyses.

Hits. We analyzed the proportion of old items that were correctly identified as having been in the choice using a 2 (aligned in choice: yes, no) × 2 (age group: younger, older) ANOVA. There were marginally more hits to alignable items ($M = 0.93 \pm 0.01$) than to nonalignable items ($M = 0.91 \pm 0.02$), $F(1, 78) = 3.88$, $MSE = 0.01$, $p < .06$, $\eta_p^2 = .05$. There were no other significant effects (both Fs < 1.00, $p > .3$; see Table 5).

False alarms. A 2 (alignable with old items: yes, no) × 2 (age group: younger, older) ANOVA for the number of new features that were falsely identified as old revealed that, as in Experiment 1, new features that were alignable with old features were more likely to be falsely recognized ($M = 0.51 \pm 0.06$) than new features that were not alignable with any old features ($M = 0.25 \pm 0.06$), $F(1, 78) = 111.85$, $MSE = 0.02$, $p < .001$, $\eta_p^2 = .59$. In addition, older adults were more likely to respond incorrectly to new items ($M = 0.45 \pm 0.07$) than were younger adults ($M = 0.32 \pm 0.07$), $F(1, 78) = 5.58$, $MSE = 0.12$, $p < .05$, $\eta_p^2 = .07$, but there was no interaction of age and alignability, $F(1, 78) = 0.32$, $\eta_p^2 = .00$ (see Table 5).

Table 5
Recognition and Source-Monitoring Accuracy for Alignable and Nonalignable Choice Option Features in Experiment 3

	Alignable features		Nonalignable features	
Accuracy measure	*M*	*SE*	*M*	*SE*
Younger adults				
Hits	.95	.02	.91	.02
False alarms	.44	.04	.19	.04
d′	1.55	0.13	2.18	0.14
C	−.60	.08	−.16	.07
Source accuracy	.85	.03	.83	.03
Older adults				
Hits	.92	.02	.90	.02
False alarms	.58	.04	.31	.04
d′	1.02	0.13	1.78	0.14
C	−.77	.08	−.32	.07
Source accuracy	.71	.03	.72	.03

Recognition accuracy. A 2 (alignability: alignable, nonalignable) × 2 (age group: younger, older) ANOVA for d' revealed that, as in Experiment 1, participants were more accurate for nonalignable features ($M = 1.95 \pm 0.27$) than for alignable features ($M = 1.43 \pm 0.28$), $F(1, 78) = 49.93$, $MSE = 0.39$, $p < .001$, $\eta_p^2 = .39$. Younger adults had higher d' scores ($M = 1.86 \pm 0.23$) than older adults did ($M = 1.40 \pm 0.23$), $F(1, 78) = 8.00$, $MSE = 1.07$, $p < .01$, $\eta_p^2 = .09$. Again, there was no interaction of age and alignability, $F(1, 78) = 0.45$, $\eta_p^2 = .01$ (see Table 5).

Response bias. A 2 (alignability: alignable, nonalignable) × 2 (age group: younger, older) ANOVA revealed that, as in Experiment 1, participants had a more liberal response bias for alignable features ($M = -0.68 \pm 0.11$) than nonalignable features ($M = -0.24 \pm 0.11$), $F(1, 78) = 119.70$, $MSE = 0.07$, $p < .001$, $\eta_p^2 = .61$. Older adults had a more liberal response bias in general ($M = -0.54 \pm 0.14$) than younger adults ($M = -0.38 \pm 0.14$), but the difference was not quite significant, $F(1, 78) = 2.89$, $MSE = 0.38$, $p = .09$, $\eta_p^2 = .04$. There was no interaction of age and alignability, $F(1, 78) = 0.00$, $\eta_p^2 = .00$.

Source attributions. A 2 (aligned in choice: yes, no) × 2 (age group: younger, older) ANOVA of the proportion of correctly recognized items that were correctly attributed to an option revealed that, as expected, younger adults had higher source attribution accuracy ($M = 0.84 \pm 0.05$) than older adults ($M = 0.72 \pm 0.05$), $F(1, 77) = 13.99$, $MSE = 0.04$, $p < .001$, $\eta_p^2 = .15$. However, there were no effects of alignability (both Fs < 1.00, $p > .6$).

Source attributions of alignable new features. As in Experiment 1, we examined what proportion of the new features was attributed to the alignable source or the similar source. As before, new features that could be directly compared with old features were more likely to be attributed to the alignable source ($M = 0.30 \pm 0.05$) than to the same source as the comparable old feature

($M = 0.21 \pm 0.04$), $F(1, 78) = 8.50$, $MSE = 0.04$, $p < .01$, $\eta_p^2 = .10$. Age did not interact significantly with attribution type, $F(1, 78) = 2.44$, $p > .1$, $\eta_p^2 = .03$.

Emotional aspects of the memories. Previous studies have found that older adults are biased against negative information in their memory and attention (Charles et al., 2003; Mather, 2004; Mather & Carstensen, 2003). In the choice scenarios we used in this experiment, each of the features was either positive (e.g., "spacious kitchen" for one of the apartments) or negative (e.g., "on a noisy street"). Thus, we could examine whether there were age differences in memory for positive and negative features.

Indeed, there was an Age × Valence interaction for d'. Older adults recognized positive features more accurately ($M = 1.21 \pm 0.19$) than negative features ($M = 0.99 \pm 0.21$), whereas younger adults showed little difference in accuracy between positive ($M = 1.42 \pm 0.19$) and negative features ($M = 1.47 \pm 0.21$), $F(1, 78) = 5.39$, $MSE = 0.28$, $p < .05$, $\eta_p^2 = .07$. In contrast, age did not interact with valence for C, $F(1, 78) = 0.00$, $\eta_p^2 = .00$, which indicates that a feature's valence affected how well older adults remembered it but not how biased they were to call it old. This finding replicates previous findings of positivity effects in memory with age.

Discussion

Younger adults' pattern of memory performance for the two new choice scenarios replicated Experiment 1. They made more false alarms to alignable than to nonalignable features, and, because of this high rate of false alarms, they had worse overall recognition accuracy for alignable features than for nonalignable features. They had a more liberal criterion for calling alignable features old than for calling nonalignable features old. Also replicating Experiment 1, source attributions were no more accurate for alignable features than nonalignable features. This suggests that participants paid no more attention to the associations between alignable features and other aspects of the situation than they did to such associations for nonalignable features.

In addition, there were no age differences in the impact of alignability on memory. Compared with younger adults, older adults showed a similar effect of alignability for correct and incorrect recognition judgments and had a similar response bias favoring alignable features. Also like younger adults, they showed no difference in their overall source attribution accuracy for alignable and nonalignable old features, and when they incorrectly remembered new features as being part of the choice, they tended to attribute them to increase the alignability of the two options.

On the surface, the similar degree of influence of alignability among older and younger adults suggests that alignment during choice or retrieval does not require self-initiated processes (e.g., planning, organizing, or noting relations), which typically decrease with age as a result of decline in prefrontal brain regions (Prull et al., 2000). However, it is possible that alignment processes do require strategic processing but that (a) the older and younger participants in our study were unusually well matched on their ability to engage in self-initiated processing or (b) strategic processing is more influential in creating aligned representations among one age group than among the other age group. Thus, in Experiments 4A and 4B, we included measures of participants' strategic processing abilities.

Experiment 4A

In this experiment, we investigated whether there are age differences in the effects of alignability on free recall and how the influence of alignability might be associated with the ability to engage in strategic processing. Strategic memory tasks affected by the integrity of the frontal lobes include source memory, list discrimination, judging frequency, judging recency, subjective organization, and temporal ordering (Prull et al., 2000), and there are individual differences in strategic processes associated with frontal region functioning among both older and younger adults (Glisky, Polster, & Routhieaux, 1995; Kane & Engle, 2002). We selected three tasks to measure individual differences in strategic processes. The first, the Wisconsin Card Sorting Task (WCST), assesses the ability to identify abstract categories and shift set (Heaton, 1981). Patients with lesions in dorsolateral prefrontal regions are less able to shift set than are other patients with brain lesions (Milner, 1963). Another test was the Animal Naming Test (Kertesz, 1982), a task measuring the ability to generate words in response to a category cue. It also has been associated with frontal lobe functioning (Baldo & Shimamura, 1998; Warkentin & Passant, 1997). We also included a sentence span task (Daneman & Carpenter, 1980) that measures working memory processes and is correlated with performance on many tasks requiring strategic processes (Engle, 2002; Waters & Caplan, 2003). Including these tasks allowed us to see whether poor strategic processing was associated with less of a benefit for alignable old features in memory among both younger and older adults.

Method

Participants. Forty-four younger adults ($M = 21.3$ years, $SD = 3.17$) and 48 older adults ($M = 72.6$ years, $SD = 4.86$) participated. One additional younger adult participated but was replaced because he could not be reached for the follow-up memory test. Younger adults, on average, had completed less education ($M = 14.91$ years, $SD = 1.91$) and scored lower on the Nelson–Denny (Brown, Fishco, & Hanna, 1993) vocabulary measure ($M = 15.32$, $SD = 3.73$) than older adults (education, $M = 16.48$ years, $SD = 2.91$; vocabulary measure, $M = 20.98$, $SD = 2.70$), $t(90) = 3.04$, $p < .01$, for education, and $t(90) = 8.38$, $p < .001$, for vocabulary. In contrast, younger adults did better on the animal naming task ($M = 33.09$, $SD = 7.96$) than the older adults ($M = 28.25$, $SD = 6.70$), $t(90) = 3.17$, $p < .01$. Younger adults also achieved more categories in the WCST ($M = 5.30$, $SD = 1.52$) than older adults ($M = 4.60$, $SD = 1.85$), $t(86) = 1.94$, $p < .06$. On the sentence span task, the number of sentences completed was not significantly different for younger ($M = 18.21$, $SD = 10.59$) and older adults ($M = 16.00$, $SD = 10.02$), $t(90) = 1.03$, $p = .31$.

Materials. We used the same choice materials as those in Experiment 3, with the exception of the memory test, which was replaced by a free recall test.

Procedure. When the experimental session was first scheduled, participants were informed that it involved a follow-up phone call the day after the lab visit. In the session, participants first completed the demographic questionnaires and the other measures, including the decision search task in Experiment 4B. Then the health plan choice was presented on the first page of a questionnaire booklet, followed by the apartment choice. We then scheduled the participants' follow-up phone call. When participants were called, they were reminded of the two decisions and asked to recall as many features as they could from the health plan choice options and then from the apartment choice options.

Coding. Features were coded by two coders using the same method as in Experiment 2. Interrater reliability was 89%, and discrepancies were resolved by discussion. Most recalled features could be matched to one of the stimulus set features, but 19 features recalled by younger adults (4% of all features they recalled) and 41 features recalled by older adults (10% of all features they recalled) were entirely new features. These features were not analyzed further, as they did not inform the question of whether features are more likely to be recalled when they help make the options more alignable than when they do not contribute to alignability.

Results

Initial analyses revealed that results were the same for the two scenarios. Thus, to simplify the following analyses we did not include scenario as a factor.

Correct recall. We analyzed the number of old features that were correctly identified as from the choice scenarios using a 2 (aligned in choice scenario: yes, no) × 2 (age group: younger, older) ANOVA. On average, participants recalled more alignable features ($M = 4.31 \pm 0.55$) than nonalignable features ($M = 2.65 \pm 0.44$), $F(1, 90) = 33.27$, $MSE = 3.80$, $p < .001$, $\eta_p^2 = .27$. As expected, younger adults recalled more previously seen features ($M = 8.25 \pm 1.17$) than older adults did ($M = 5.67 \pm 1.10$), $F(1, 90) = 10.03$, $MSE = 15.28$, $p < .01$, $\eta_p^2 = .10$. As in Experiment 3, the interaction of alignability and age group was not significant, $F(1, 90) = 2.02$, $p > .15$, $\eta_p^2 = .02$ (see Table 6).

False recall. We used a 2 (alignable with old items: yes, no) × 2 (age group: younger, older) ANOVA to analyze the number of features incorrectly recalled as having been in the choice scenario. As in Experiment 2, participants' false recall included more features alignable with previously seen features ($M = 0.85 \pm 0.22$) than features not alignable with any previously seen features ($M = 0.15 \pm 0.10$), $F(1, 90) = 36.34$, $MSE = 0.63$, $p < .001$, $\eta_p^2 = .29$. In addition, as in Experiment 3, there was no interaction of alignability and age group, $F(1, 90) = 0.15$, $MSE = 0.63$, $\eta_p^2 = .00$ (see Table 6). Finally, although older adults recalled more features they had not seen ($M = 1.21 \pm 0.33$) than younger adults ($M = 0.80 \pm 0.34$), this difference did not reach significance, $F(1, 90) = 2.57$, $MSE = 3.49$, $p = .11$, $\eta_p^2 = .03$.

False recall with matching old feature. The proportion of all recalled alignable new features that were recalled with their corresponding old feature did not differ among younger ($M = 0.63 \pm 0.20$) and older adults ($M = 0.58 \pm 0.16$), $F(1, 50) = 0.15$, $\eta_p^2 = .00$. The proportion of all nonalignable old features recalled together with a matching new feature (making them alignable at retrieval) also did not differ for younger ($M = 0.20 \pm 0.10$) and older adults ($M = 0.24 \pm 0.10$), $F(1, 80) = 0.64$, $\eta_p^2 = .00$.

Table 6
Average Number of Features Recalled for Alignable and Nonalignable Choice Option Features by Younger and Older Adults in Experiment 4

Recall type	Alignable features *M*	Alignable features *SE*	Nonalignable features *M*	Nonalignable features *SE*
Younger adults				
Correct	5.16	0.40	3.09	0.32
False	0.73	0.16	0.07	0.07
Older adults				
Correct	3.46	0.38	2.21	0.31
False	0.98	0.15	0.23	0.07

Frontal measures. We divided the participants into subgroups on the basis of their age and counterbalancing condition for the decision scenario. For each frontal test, we used the median score in each subgroup to divide the subgroup into high and low performers (see Table 7 for means). Then we ran 2 (alignable: yes, no) × 2 (item type: old, new) × 2 (age group: younger, older) × 2 (counterbalancing version: 1, 2, 3, 4) × 2 (frontal task performance: high, low) ANOVAs for each frontal test, with number of features recalled as the dependent variable (see Table 8 for means). For each analysis, there was a significant or marginally significant four-way interaction of whether features were alignable, age group, frontal task performance interaction, and the type of item (see Table 9).

To understand these interactions, we conducted separate ANOVAs for old and new features. For old features, age, alignability and frontal task performance interacted for each of the frontal tasks (see Table 9). As shown in the first two columns of Table 8, younger low performers on the frontal tasks had a larger benefit for alignable compared with nonalignable old features than high performers did. The reverse was the case among older adults (see the second two columns in Table 8), who showed more benefit of alignability if they were high performers. For the new features, this three-way interaction was not significant for any of the frontal tasks. Thus, strategic task performance was associated with the influence alignability had on accurate recall but not on false recall. In particular, high-strategic younger adults were less influenced by alignment than low-strategic younger adults were when remembering choices, whereas high-strategic older adults were more influenced by alignment than were low-strategic older adults.

The similarity in how each of the frontal tests predicted performance is striking when one considers that participants' scores on the three measures were not highly correlated. The only significant correlation among the tests was between the WCST and the sentence span task ($r = .25$, $p < .05$). Only 30% of the participants were categorized the same way (low or high scorers) for all three tests. Sixty-seven percent were categorized the same way for two of the tests (chance would lead these values to be 25% and 38%). Thus, these tests seem to measure somewhat different types of self-initiated strategic processing that each help predict how people remember choice options.

Emotional quality of recalled features. Looking at the number of negative and positive features recalled did not reveal a significant Age × Valence interaction, $F(1, 90) = 0.67$, $\eta_p^2 = .01$, in contrast with the recognition data in Experiment 3. Thus, something about free recall of choice options that include some alignable features reduces the impact of older adults' positivity bias.

Discussion

This experiment reveals that, like younger adults, older adults were more likely to both correctly and incorrectly remember features when they were alignable than when they were not. There were no age differences in the likelihood of recalling alignable features, which extends the results of Experiment 3 to free recall. However, this experiment suggests that there are age differences in

Table 7
Average Scores on the Frontal Tasks Within the Low- and High-Performing Younger and Older Groups

	Wisconsin Card Sorting Task				Sentence span				Animal naming			
	Low scorers		High scorers		Low scorers		High scorers		Low scorers		High scorers	
Group	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Younger adults	2.67	0.30	6.00	0.15	12.00	1.31	27.00	1.48	26.50	1.10	38.29	1.00
Older adults	3.00	0.20	6.00	0.18	10.49	1.12	28.13	1.66	23.13	1.00	33.38	1.00

how strategic processing abilities affect choice comparison processes. For younger adults, high frontal scores were associated with less of a memory advantage for alignable old features, whereas for older adults, high frontal scores were associated with more of an advantage for these features. The fact that the frontal tests predicted performance for old features but not for new features suggests that having high strategic processing abilities affects how options are initially compared and encoded but does not affect the likelihood of inferring new features to make options more comparable. Experiment 4B tests this possibility that strategic processing is associated with differences in the way that options are initially compared. In particular, it tests a prediction suggested by the results of Experiment 4A: Older adults with high frontal scores make more feature-based comparisons across options (focusing on how they are alignable) than those with low frontal scores, whereas younger adults with high frontal scores make fewer feature-based comparisons than those with low frontal scores.

Experiment 4B

There is little previous information on how older adults make comparisons during choice. However, one study (M. M. S. Johnson, 1990) found that, when examining information about potential cars to purchase in a decision grid, older adults were more likely to organize their search by dimension (e.g., looking at the safety record for each car, then moving on to another dimension) than were younger adults. In contrast, younger adults were more likely to organize their search by option (e.g., looking at all the features of one car, then moving on to the next). Increased use of feature-based strategies should lead people to be more influenced by alignability, as it is only during feature-based comparisons that alignability can be established. However, the finding of age differences in search patterns does not appear to be reliable. The same investigator failed to replicate the age differences in two subsequent studies using similar materials (M. M. S. Johnson, 1993, 1997), as did another investigator using an insurance policy choice (Hartley, 1990). Our findings in Experiment 4A suggest that even when no overall age differences are found, if participants are separated into high- and low-frontal groups, there should be an interaction of frontal score level and age for search strategies. For older adults, increased strategic processing abilities should increase feature-based comparisons, whereas for younger adults, increased strategic processing abilities should increase option-based comparisons.

Method

Participants. All the participants from Experiment 4A also completed this study.

Materials. We used M. M. S. Johnson's (1990) decision grid, in which comparative information is available for the following dimensions for six cars: fuel economy, riding comfort, maintenance cost, safety record, handling, interior roominess, purchase price, styling, and resale value. The car options were organized in columns (with evaluative dimensions in rows) for half the participants and in rows (with dimensions in columns) for the other half. Each grid square contained a description that was positive (e.g.,

Table 8
Number of Alignable and Nonalignable Old and New Features Recalled by High and Low Performers on Each Frontal Task in Experiment 4A

	Correct recall (old features)				False recall (new features)			
	Younger adults		Older adults		Younger adults		Older adults	
Frontal task	Alignable	Nonalignable	Alignable	Nonalignable	Alignable	Nonalignable	Alignable	Nonalignable
Wisconsin Card Sorting								
High	5.13 (.47)	3.30 (.35)	3.38 (.55)	2.29 (.42)	0.71 (.18)	0.07 (.09)	0.83 (.22)	0.21 (.10)
Low	6.68 (1.11)	2.00 (.84)	3.22 (.59)	2.15 (.45)	1.00 (.44)	0.05 (.21)	1.23 (.23)	0.30 (.11)
Sentence span								
High	5.29 (.64)	3.86 (.44)	4.04 (.71)	1.66 (.49)	0.89 (.24)	0.05 (.11)	0.85 (.27)	0.21 (.12)
Low	5.03 (.56)	2.31 (.38)	3.17 (.47)	2.46 (.32)	0.64 (.21)	0.04 (.10)	1.01 (.18)	0.27 (.08)
Animal naming								
High	5.33 (.51)	3.67 (.40)	3.63 (.51)	1.88 (.40)	0.79 (.21)	0.13 (.09)	1.13 (.21)	0.42 (.09)
Low	5.35 (.55)	2.50 (.43)	3.29 (.51)	2.54 (.40)	0.70 (.23)	0.00 (.10)	0.83 (.21)	0.04 (.09)

Note. Standard errors are in parentheses.

Table 9
Age × Alignable × Frontal Task F and η_p^2 Values in Experiment 4A

	Task					
	Wisconsin Card Sorting		Sentence span		Animal naming	
Features	*F*	η_p^2	*F*	η_p^2	*F*	η_p^2
Old	4.70*	.06	6.89*	.08	4.52*	.06
New	0.00	.00	0.49	.01	0.01	.00

* $p < .05$.

"very good," "affordable"), neutral (e.g., "average"), or negative (e.g., "very poor," "expensive").

Procedure. Participants completed this task before completing the frontal tasks and choices described in Experiment 4A. They were seated in front of a computer screen and told they would be asked to make a choice among several cars. A screen with the decision grid row and column headers (the car names and features) was displayed as the experimenter explained how to move the mouse over the grid squares and click in boxes to see their contents. No boxes were revealed until the participant indicated he or she understood the task and the program advanced to the actual decision grid screen. Participants could spend as long as they liked looking at the various features; each time they moved on to the next feature the contents of the previous box were hidden once again. When they were ready to make their decision, they pressed a button at the bottom of the screen and then were asked to select one of the cars.

Results

Decision search strategies. Like M. M. S. Johnson (1990), we categorized each move from looking at one feature to another feature as either a within-dimension shift, a within-option shift, or neither. For each participant we computed the proportion of moves that were of each type. A 2 (age: younger, older) × 2 (move type: within dimension, within option) ANOVA revealed no interaction, $F(1, 90) = 0.94$, $MSE = 0.14$, $p > .3$, $\eta_p^2 = .01$, thus failing to replicate M. M. S. Johnson's findings (see bottom row of Table 10 for means). In addition, follow-up independent means *t* tests, performed separately for each type of shift, also failed to reveal any age differences. To see whether this failure to replicate might be due to a lack of sufficient power, we computed the effect size in M. M. S. Johnson's study (Thalheimer & Cook, 2004). For the *t* test comparing younger and older adults' within-dimension shifts, Cohen's *d* was 1.51, a very large effect size. With our sample size, we had over 99% power to detect an effect size that large (Cohen, 1988). The following analyses looking at frontal task performance suggest that M. M. S. Johnson's (1990) older and younger adult samples both happened to excel at strategic processing.

Frontal task performance and strategies. Within the younger and older groups, we determined the median score for each of the frontal tests and categorized participants as either high or low scorers. Age (younger, older) × Move Type (within dimension, within option) × Frontal Task Performance (high, low) ANOVAs revealed significant interactions of age and move type with performance for the WCST and the sentence span task. The pattern with the animal naming task, as shown in Table 9, was similar, but the interaction was not significant. In general, high-frontal older adults were more likely to compare features across dimensions than to evaluate one option at a time, whereas low-frontal older adults did not show a preference for one strategy over the other. In contrast, among the younger adults, the low-frontal group preferred the within-dimension strategy, whereas the high-frontal group did not.

Emotional aspects of search strategies. The proportion of the total decision search time spent viewing negative features was lower for older adults ($M = 0.23 \pm 0.03$) than for younger adults ($M = 0.28 \pm 0.03$), whereas the proportion of time spent viewing positive features was higher for older adults ($M = 0.54 \pm 0.04$) than for younger adults ($M = 0.48 \pm 0.04$), $F(1, 90) = 6.08$, $MSE = 0.02$, $p < .05$, $\eta_p^2 = .06$.

Table 10
Proportion of Within-Dimension and Within-Option Feature Search Moves by High and Low Performers on Each Frontal Task in Experiment 4B

	Search patterns				Age × Frontal Status × Search Pattern	
	Younger adults		Older adults			
Frontal task	Dimension	Option	Dimension	Option	*F*	η_p^2
Wisconsin Card Sorting						
High	.39 (.04)	.47 (.05)	.54 (.05)	.33 (.06)	4.18*	.047
Low	.48 (.09)	.36 (.09)	.41 (.06)	.50 (.06)		
Sentence span						
High	.33 (.06)	.53 (.06)	.54 (.07)	.36 (.07)	4.04*	.044
Low	.46 (.05)	.38 (.06)	.45 (.05)	.44 (.05)		
Animal naming						
High	.36 (.06)	.48 (.06)	.48 (.06)	.38 (.06)	1.05	.012
Low	.45 (.06)	.41 (.06)	.47 (.05)	.44 (.06)		
Across all participants	.40 (.04)	.45 (.04)	.48 (.04)	.41 (.04)		

Note. Standard errors are in parentheses.
* $p < .05$.

Discussion

This experiment reveals that, among those younger and older adults who are most effective at strategic thinking, strategies differ quite markedly by age group. For older adults, being more effective at strategic processing was associated with more feature-based comparisons (Experiment 4B) and more impact of alignability on later memory (Experiment 4A). The reverse was the case for younger adults. In addition, the data reveal an interesting pattern in which older adults focused more than younger adults on the positive features during their search and less on the negative features.

General Discussion

Previous research demonstrates that alignable choice features are more likely to be recalled than nonalignable features (Zhang & Markman, 1998, 2001). In four experiments, we found that people also remember new features that fill comparison gaps, making options more comparable. Thus, alignability has a cost as well as a benefit for memory. In fact, recognition accuracy was lower for alignable features than for nonalignable features, as people had a bias to identify nonpresented alignable features as having been associated with choice options. In addition, across the various conditions in the recall experiments, between 15% and 47% of the nonalignable old features recalled were recalled with corresponding new features to make them more alignable.

Alignable False Memories Go Beyond Similarity

Alignable new features are, of course, similar to previously seen features. Although they have different affective valence, they often share some of the same words (e.g., "campus") and concepts (e.g., attractiveness). But the pattern of our participants' misattributions of alignable new features suggests that similarity was not the primary reason these features were misremembered as part of the choice options. For example, if the first apartment was described as having "not much light at any time of day" and nothing was mentioned about sunlight for the second apartment, participants were more likely to attribute the new alignable feature "lots of sunlight" to the second apartment, to make the two apartments more comparable. If the false memory for "lots of sunlight" was similarity driven, participants should have had no source bias or have been more likely to attribute it to the first apartment, the one that had a similar feature. Likewise, false recall of alignable new features such as "lots of sunlight" was typically accompanied by recall of matching old features (e.g., "not much light at any time of day"). Such false memories are not just similarity-based errors but instead are distinct new features.

Aging and Alignable False Memories

In Experiments 3 and 4A, we compared younger and older adults' memories of choice options. These experiments replicated Experiments 1 and 2; both younger and older adults frequently had false memories of features that contrasted with features they had seen, making the two options more alignable than they had been originally. In both experiments, there were no age differences in how much alignability influenced memory.

However, Experiments 4A and 4B suggest that there are age differences in the way that alignability exerts its influence. Older participants with high scores on tasks requiring strategic processing associated with prefrontal brain region functioning showed a larger advantage for remembering alignable old features relative to nonalignable old features. Thus, for older adults, being good at strategic processes such as planning, organizing, generating solutions, and noting relations was associated with more benefits from alignability for accurate recall. Performance on the frontal tasks revealed the opposite relation for younger adults. They showed less of an advantage for alignable features in their correct recall if they scored highly on the frontal tasks than if they scored below the median. There were no effects of frontal task performance on the influence of alignability on false recall. Thus, frontal task performance appears to predict the strategies people use to compare existing information but not the degree to which they are influenced by alignability in inferring or retrieving new features.

Decision Search Strategies

This link between frontal task performance and strategies during choice was supported in Experiment 4B, in which we tracked which features participants examined during a choice. We found that, overall, there were no age differences in how often participants used feature-based comparison processes (comparing features from the same dimension across options) and option-based comparison processes (examining the features from one option before moving on to the features from another option). However, as in Experiment 4A, there was an interaction of age and frontal task performance. For older adults, high frontal task performance was associated with increases in feature-based comparisons. In contrast, for younger adults, high frontal task performance was associated with increases in option-based comparisons.

Goal-Directed Nature of Comparison Strategies

Scores on the frontal tasks indicate how well people can implement task-specific goals. Our findings are consistent with previous research in a variety of contexts in that the goals people are most interested in fulfilling depend on their age (Blanchard-Fields & Camp, 1990; Blanchard-Fields, Camp, & Casper Jahnke, 1995; Folkman, Lazarus, Pimley, & Novacek, 1987). In particular, emotional goals become more salient as people approach the end of life, whereas for younger adults information seeking is a more prominent goal (Carstensen, 1992, 1995; Carstensen et al., 1999). In our study, younger adults with high frontal scores focused on finding out everything they could about each option before moving onto the next one. Decisions that involve evaluating each option separately tend to yield more accurate decisions but require more effort than strategies that compare features across dimensions (Payne, Bettman, & Johnson, 1993).

In contrast, older adults with high frontal scores focused on feature-based comparisons. Previous research indicates that feature-based strategies are more likely to be used when the emotional aspects of the decision are emphasized (Luce et al., 1997). This appears to be because feature-based comparisons help diminish the conflict inherent in choice. For example, choosing which job to take on the basis of a feature-based comparison by salary is straightforward and does not involve any trade-offs. In contrast, forming an overall evaluation of each job option and taking the one with the highest evaluation makes the trade-offs among options more salient, increasing regret. Thus, it is possible that older adults were more focused on emotional goals when making their choices and that those older adults with high frontal scores were best equipped to implement a strategy to help avoid decision conflict and negative affect.

The possibility that older adults were more focused on emotional goals than younger adults were while making their choices is supported by another aspect of the decision search results. Older adults spent a greater proportion of their time looking at positive features of the options and a smaller proportion of their time looking at negative features than did younger adults. Experiment 3 also replicates previous findings (Mather & Carstensen, 2004) that older adults recognized positive features of choice options better than negative features, whereas younger adults did not show this positivity bias. It is interesting that, in contrast, there was no Age × Valence interaction when participants recalled the features in Experiment 4A, unlike previous findings from nonalignable choices (Mather & Carstensen, 2004). This suggests that even if older adults remember positive features more accurately than negative features, if they attempt to make the option features alignable when recalling them, they may come up with new negative features to fill in comparison gaps.

Our findings help resolve a contradiction in the literature. In one study, researchers found that older adults make more feature-based comparisons than do younger adults (M. M. S. Johnson, 1990), whereas subsequent studies have failed to replicate this finding (Hartley, 1990; M. M. S. Johnson, 1993, 1997). Previously, M. M. S. Johnson's (1990) finding has been interpreted as meaning that older adults use less complex strategies because they have a diminished working memory capacity (Sanfey & Hastie, 2000; Yates & Patalano, 1999) or because they are less capable of engaging in strategic, controlled processing (Peters et al., 2000). Our findings refute this possibility, as older adults with the best working memory performance were most likely to use feature-based comparison strategies. Instead, older and younger adults differ in terms of which strategy they choose to use when they have the cognitive resources to effectively implement a complex strategy.

Role of Response Biases

Performance on frontal tasks predicted the search strategies used during choice and the likelihood of remembering more alignable old features than nonalignable old features. But performance on these tasks was not associated with the likelihood of retrieving alignable false memories. Thus, it appears that strategic processing influences the way that people compare options but does not affect the bias they have to make them more comparable when later remembering them. In both experiments testing recognition memory (Experiments 1 and 3), participants had a more liberal response bias for alignable features than for nonalignable features, which indicates that they were more likely to identify alignable features as old. Therefore, response biases at the time of retrieval play at least some role in alignable false memories. Furthermore, the delay conditions in Experiment 1 revealed that over time, participants' bias to identify alignable features as old increased faster than their bias to identify nonalignable features as old. Thus, as overall accuracy grew worse, alignability had even more influence on recognition judgments. This retrieval bias favoring alignable features also increased over time in Experiment 2, as indicated by the proportion of correctly recalled nonalignable old features that were recalled together with a contrasting new feature, making them alignable.

Conclusions

What is remembered about decisions can be as important as the decision itself, especially in determining how much regret or satisfaction one experiences. Yet, like any episodic or autobiographical memory, memories for choice options are subject to memory distortion (e.g., Mather & Johnson, 2000; Mather, Shafir, & Johnson, 2000, 2003). In this study, we found that new features are more likely to be falsely recognized or recalled if they are easy to compare with previously seen features. The result is a memory in which the choice options are more easily compared than they were to begin with—the nature of each option has been molded to better contrast with the features in the other option.

This study also provides some insight into older adults' decision-making processes. There is little previous research investigating the way older adults make comparisons during choices, and what has been done provides contradictory results (Hartley, 1990; M. M. S. Johnson, 1990, 1993, 1997). Our studies indicate that older adults with the least decline in strategic processes (and therefore those best equipped to implement goals) are more likely to use feature-based decision comparison strategies, which may help them avoid decision conflict.

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