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The role of metacognition and schematic support in younger and older adults' episodic memory

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Abstract
Older adults experience deficits in associative memory. However, age-related differences are reduced when information is consistent with prior knowledge (i.e., schematic support), suggesting that episodic and semantic memory are interrelated. It is unclear what role metacognitive processes play in schematic support. Prior knowledge may reduce encoding demands, but older adults may allocate cognitive resources to schema-consistent information because it is more meaningful. We examined metacognitive awareness of and control over associative information that was consistent or inconsistent with prior knowledge. In Experiment 1, participants self-paced their study of grocery items paired with either market prices or unusually high prices and were tested on the exact price of each item over four study-test lists with new items on each list. In Experiment 2, participants studied items for a fixed time but made judgments of learning (JOLs) at encoding. Older adults better remembered the prices of market-value items than overpriced items. In Experiment 1, younger and older adults studied overpriced items longer than market-priced items, consistent with a discrepancy reduction model of self-regulated learning, but study time did not relate to later recall accuracy, suggesting a labor-in-vain effect. In Experiment 2, participants gave higher JOLs to market-priced items than overpriced items and were generally metacognitively aware of the benefits of schematic support. Together, these results suggest that the benefits of schematic support may not be dependent on or influenced by metacognitive control processes, supporting the hypothesis that episodic memory may be less distinct from semantic memory in younger and older adults.

Keywords Aging · Metacognition · Associative memory · Self-paced learning · Schematic support

Introduction

The ability to remember associative information, such as names and faces or medications and side effects, is crucial in everyday life. However, older adults show a specific impairment in associative memory (e.g., Chalfonte & Johnson, 1996). Naveh-Benjamin (2000) proposed an associative deficit hypothesis to explain this impairment, which has been supported by numerous studies using a variety of stimuli, including face-name pairs (Naveh-Benjamin et al., 2004), pairs of objects (Naveh-Benjamin et al., 2003), and object-spatial location pairs (Siegel & Castel, 2018; see Old & Naveh-Benjamin, 2008, for a meta-analysis).

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Although well documented, the associative deficit in older adults can be reduced or even eliminated when the to-be-learned information is consistent with semantic knowledge or schemas (e.g., Amer et al., 2018; Delhaye et al., 2019; Fine et al., 2018; Kuhns & Touron, 2019; Mohanty et al., 2016; Smyth & Naveh-Benjamin, 2018; cf. Arbuckle et al., 1994). For example, age-related differences in associative recognition are smaller when word pairs are related than when they are unrelated (Naveh-Benjamin, 2000). In addition, Castel (2005) showed that older adults performed similarly to younger adults when remembering prices of grocery items that were consistent with prior schematic knowledge (i.e., market value), but had worse memory for unusual (i.e., overpriced) prices. This memory benefit, termed schematic support (Craik & Bosman, 1992), has been found with a variety of stimuli and conditions (e.g., Gallo et al., 2019; Peterson et al., 2017; Umanath & Marsh, 2014).

In a pioneering book chapter, Tulving (1972) proposed a distinction between episodic (i.e., memory for specific events) and semantic memory (i.e., general knowledge and language), arguing that there are fundamental differences between these two forms of memory. Decades of research in cognitive aging has used this distinction to help elucidate how older adults maintain semantic knowledge, like language abilities, but show reduced episodic memory performance (Lövdén et al., 2004; Riby et al., 2004; Rönnlund et al., 2005). However, recent work has suggested the distinction between episodic and semantic memory is less clear than previously thought (e.g., Greenberg & Verfaellie, 2010; Irish & Piguet, 2013). Specifically in aging research, it has been found that older adults can rely on semantic knowledge to bolster episodic memory performance (Castel, 2005; Castel et al., 2013a; Kuhns & Touron, 2019; Peterson et al., 2017; Umanath & Marsh, 2014), which further suggests that these two types of memory may be interdependent, at least in some cases. However, it remains unclear why schematic support benefits memory, especially in older age.

One explanation for the benefits of schematic support is that schemas facilitate the binding of information in memory. Some work has shown that activating a schema prior to encoding leads to better memory for information that is consistent with that schema for both younger and older adults (Besken & Gülgöz, 2009). This memory benefit may occur via the activation of a larger semantic network that makes information easier to retrieve, and this may be somewhat automatic. Indeed, recent work has demonstrated that schema-consistent information is better remembered when under time pressure at retrieval, suggesting schema-consistent information may require less controlled retrieval processes (Amer et al., 2018). Schematic support may also reduce reliance on effortful, self-initiated processing at encoding (McGillivray & Castel, 2010; Soederberg Miller, 2009), which can benefit older adults' memory, as they are less likely to engage in more effortful processing during encoding (Whiting & Smith, 1997).

However, an alternative explanation of the benefits of schematic support is that information that is consistent with prior knowledge may be more meaningful than arbitrary information. Some work shows that older adults are more likely to allocate attention and cognitive resources (i.e., metacognitive control processes) to information that is meaningful (Fung et al., 2018; Hess, 2014). Thus, motivational and metacognitive processes may also influence memory for realistic associative information.

Metacognition is often considered in terms of monitoring and control processes (see Koriat & Goldsmith, 1996; Nelson, 1996; Son & Schwartz, 2002), where monitoring assesses how well one thinks they will learn or has learned information, and control refers to processes used to attempt to improve learning (e.g., re-study, stop study, study longer, etc.). Evidence regarding whether metacognitive monitoring accuracy is maintained in older age has been fairly mixed (Dodson et al., 2007; Eakin et al., 2014; Halamish et al., 2011; Hansson et al., 2008; but see Hertzog & Dunlosky, 2011). However, older adults tend to rely on many of the same cues (e.g., encoding fluency) as younger adults when making metacognitive judgments (Connor et al., 1997; Hines et al., 2009; Rast & Zimprich, 2009) and may become better at successfully monitoring memory performance with greater practice and task experience, even without feedback (e.g., McGillivray & Castel, 2017). Thus, older adults may show accurate metacognitive monitoring when given multiple study-test trials (Castel et al., 2015; Hertzog et al., 2010; see Siegel et al., 2020).

Intact metacognitive monitoring of memory abilities can influence the extent to which one engages in more top-down metacognitive control processing (Nelson, 1996). As such, younger and older adults may strategically allocate greater cognitive resources to different items, depending on item-level factors like difficulty or importance (Ariel et al., 2009; Dunlosky & Ariel, 2011; Dunlosky & Hertzog, 1998b). Numerous studies examining self-paced study have shown that items judged to be more difficult to remember are studied longer on subsequent lists (Hertzog & Dunlosky, 2011; Son & Metcalfe, 2000; Thiede & Dunlosky, 1999), known as the discrepancy reduction hypothesis (Dunlosky & Hertzog, 1998b). Older adults tend to adopt this strategy when items do not differ objectively in terms of value or difficulty. For example, one experiment tested age differences in study-time allocation for associative information across multiple study-test lists and found that older adults studied all item-pairs longer than younger adults, and both age groups studied incorrect pairs on subsequent lists longer than correctly remembered pairs (Hines et al., 2009). In Hines et al. (2009), older adults performed just as well as younger adults by the end of the task, suggesting that extra study time led to a corresponding benefit in memory performance. Because items that are inconsistent with semantic knowledge may be judged as more difficult, these items may be studied longer, even if they are less meaningful than realistic item-price pairs. Additionally, older adults may find the overpriced items more difficult than younger adults, leading older adults to demonstrate a discrepancy reduction strategy to a greater extent than younger adults.

Studies examining metacognitive control have shown that older adults can learn to use metacognitive monitoring to vary study time and improve associative memory performance when study is self-paced (e.g., Dunlosky et al., 2003; Hines et al., 2009). In addition, Castel et al. (2013b) found that both older and younger adults strategically vary study time to focus on the most valuable information, and that the increase in study time for high-value items is associated with greater memory performance for those items. Thus, older adults are able to engage in metacognitive control processes to improve memory for important information. This "meaningfulness" hypothesis, then, would predict that older adults study market-value items longer than overpriced items because they are more meaningful.

However, other work has found evidence for a labor-in-vain effect, wherein increased study time does not correspond to a benefit in memory performance (Nelson & Leonesio, 1988). Specifically, a labor-in-vain effect occurs when participants study items longer than is needed to achieve the desired level of performance. Older adults may be particularly unlikely to benefit from extra study time, given that they are less likely to spontaneously use effective strategies and therefore may not use study time effectively (Bouazzaoui et al., 2010; Rogers et al., 2000; but see Bottiroli et al., 2010, for an example of how task characteristics can influence self-initiated strategy use). In an associative memory task, Price et al. (2010) found that older adults studied more items than younger adults and studied the items longer, but still had lower memory performance. However, older adults have been shown to improve performance after greater task experience with self-paced study (Hertzog et al., 2012). Thus, older and younger adults may use study time effectively to improve memory for difficult items, but we may find evidence for a labor-in-vain effect, wherein additional study time and task experience does not produce better recall performance.

The current research

In two experiments, we examined age differences in metacognitive accuracy (measured by judgments of learning; JOLs) and metacognitive control processes (measured by study time allocation) for common grocery items and prices. Prices were presented as either market value (i.e., schema-consistent) or were overpriced (i.e., schema-inconsistent) as in Castel (2005). In both experiments, participants studied items over four study-test lists, with each list containing new items, and were tested on the exact price of each item.

In Experiment 1, younger and older adult participants self-paced their study of the grocery items without limits, and we assessed participants' study time strategy. Competing hypotheses suggested participants may use a discrepancy reduction strategy, wherein participants study overpriced items longer because of their difficulty. On the other hand, a meaningfulness account suggests participants may study market-value prices longer. In addition, we were interested in whether study time would correspond to improvements in memory performance in either age group. Again, there were competing hypotheses such that additional study time (for either price category) may lead to improvements in memory performance at the item level. The labor-in-vain hypothesis, however, suggests that additional study time may not lead to better memory.

In Experiment 2, we assessed participants' metacognitive awareness of the benefits of schematic support on memory performance by having participants make JOLs at encoding. This allowed us to assess whether participants are aware of schematic support without the influence of top-down control processes (i.e., study time).

Experiment 1

In Experiment 1, we assessed younger and older adults' self-paced study time for market value and overpriced items and tested participants' later recall of the items' exact prices. According to the discrepancy reduction model of self-regulated learning (Dunlosky & Hertzog, 1998b), we hypothesized that participants may study overpriced items longer than market-value items because of their greater difficulty. However, a meaningfulness account, where participants allocate more resources to meaningful information, would predict that participants (and older adults in particular) devote more study time to market-value items because they are consistent with semantic knowledge.

Experiment 1 also examined whether differences in study time were related to changes in recall performance. We hypothesized that the longer an item is studied, the more likely it should be accurately recalled, consistent with some prior work (e.g., Castel et al., 2013b; Dunlosky et al., 2003; Dunlosky & Connor, 1997). Therefore, if overpriced items are studied longer, recall performance for these prices may improve, potentially to the level of market-value prices. In contrast, the labor-in-vain hypothesis suggests that greater study time does not necessarily lead to better memory performance.

Method

Participants Younger adult participants were 24 University of California, Los Angeles (UCLA) undergraduate students aged 19–28 years (M = 20.58, SD = 1.82; 17 females) who participated for partial fulfillment of a course requirement and 24 older adults aged 60–85 years (M = 71.96 years, SD = 7.36; 14 females) recruited from the local community and compensated $10 per hour of their participation. Older adults were in self-reported good health, made it to the lab independently, and did not report any significant visual impairments that could not be corrected by lenses. Older adults had a forward digit span score of at least four and did not report any diagnosed cognitive decline.

Materials Stimuli were 40 color images of common grocery items taken from a local grocery store website. Items included fruits and vegetables, boxed foods like pasta and cereal, canned and jarred foods like beans and peanut butter, and deli items like meat, eggs, and milk. Only one version of each item was included in the stimuli set (e.g., only one brand of cereal or eggs) and name brands were chosen so that items were not store-specific. Prices were also taken from the grocery store website and updated so that all prices ended in 9 for consistency. The realistic prices reflected local market prices as of 2018, and all produce or fresh meat prices were shown at price per pound (and participants were made aware of this). Market value prices ranged from \$0.59 to \$7.79. Consistent with Castel (2005), to create overpriced items, a randomly selected value of \$6, \$7, or \$8 was added to the market-value price. Therefore, overpriced items ranged in price from \$6.59 to \$15.79. Using this method to create overpriced items, rather than increasing the market price by a percentage, ensures that items are quickly and easily identifiable as overpriced.

Procedure All procedures were approved by the UCLA Institutional Review Board (IRB). Participants were instructed that they would be studying four lists of grocery items that may be market-priced or overpriced, and that their goal was to remember the exact price of the items. Participants were informed that all prices ended in 9 and that produce and meat items were shown at price per pound. Each of the four lists contained ten items (five market-priced and five overpriced) that appeared in a random order for each participant. The order of lists and whether each item appeared at market value or was overpriced was counterbalanced across participants.

During the study period, each item was displayed in the center of a computer screen with its price shown below in 18-pt font. Participants were instructed that they could study each item as long as they liked and should click a button on the screen or press the enter key on the keyboard to see the next item. After each list of ten items, participants were tested on the exact price of those items. During testing, each item was shown with a blank text box where the price had been, and participants were asked to recall the exact price of the item. If participants were unsure of their answer, they were asked to guess. The order of items during the test phase was random for each participant. After providing an answer for each item, participants rated their confidence in their response on a 7-point Likert scale from 1 (*Not at all confident*) to 7 (*Very confident*). At the end of all four study-test lists, participants were shown all 40 items they had studied and were asked to list all of the items that they typically buy at the grocery store and the approximate price they pay for those items. Finally, participants reported how often they went grocery shopping on a scale of 0 (*Never)* to 5 (*More than weekly)*.

Results

For the primary three-way (Age × Price × List) analysis of variance (ANOVA) reported here, we conducted a sensitivity analysis using G*Power 3.1.7 (Faul et al., 2007). The analysis revealed that with power of .80, alpha of .05, and using the default correlation among repeated measures of .50, the smallest effect size, measured as partial eta squared (η_p^2), we would reliably be able to detect is 0.02.

Memory performance Figure 1A depicts recall performance as a function of age group and price type. We first examined whether item price, list, and age group influenced memory performance, without the influence of study time, using a 2 (Price: market-priced, overpriced) × 4 (List) × 2 (Age: younger adults, older adults) mixed ANOVA, with price and list as within-subjects variables and age as a between-subjects variable. We used Greenhouse-Geisser corrections to correct for sphericity violations where relevant in all reported ANOVAs. The analysis revealed that the prices of market-priced items (M = .52, SD = .25) were remembered better than those of overpriced items (M = .37, SD = .19), $F(1, 46) = 30.00$, $p < .001$, $\eta_p^2 = 0.40$. Younger adults (M = .56, SD = .28) also correctly recalled a greater proportion of prices than did older adults (M = .33, SD = .28), $F(1, 46) = 15.83$, $p < .001$, $\eta_p^2 = 0.26$. However, the main effect of list was not significant, $F(2.39, 110.04) = 1.67$, $p = .19$, $\eta_p^2 = 0.04$, and list did not interact with age, $F(2.39, 110.04) = 0.41$, $p = .70$, $\eta_p^2 = 0.01$.

There was, however, a significant interaction between age and price type on recall performance, $F(1, 46) = 4.28$, $p = .04$, $\eta_p^2 = 0.09$. Follow-up paired-samples t-tests using Bonferroni corrections revealed that age differences were not present for prices of market-value items ($M_{younger}$ = .61, $SD_{younger}$ = .49; M_{older} = .44, SD_{older} = .50), $t(46) = 2.63$, $p = .06$, but older adults showed significantly worse recall for the unusual prices ($M_{younger}$ = .51, $SD_{younger}$ = .50; M_{older} = .22, SD_{older} = .42), $t(46) = 4.48$, $p < .001$. The interaction between list and price was also significant, $F(2.45, 112.47) = 3.67$, $p = .02$, $\eta_p^2 = .07$. To further explore this interaction, we conducted a post hoc trend analysis to examine the effect of list within each level of price type. The analysis revealed no effect of list within market-value items, $F(3, 138) = 1.65$, $p = .18$, but there was a significant negative linear trend within overpriced items, $F(3, 138) = 3.39$, $p = .02$, indicating that memory performance declined across lists for overpriced items only. Lastly, the three-way interaction between age, price type, and list was not significant, $F(2.45, 112.47) = 1.10$, $p = .35$, $\eta_p^2 = .02$.

Given the null effects, we calculated Bayes factors (BFs), which give a measure of the strength of the evidence for a given hypothesis (either the null or the alternative) based on both *a priori* hypotheses and the observed data (see Wagenmakers et al., 2016, 2017, for the benefits of using a Bayesian approach). Here, we report BF_{01} for any null effects observed, which provide a measure of strength for the null hypothesis. Jarosz and Wiley (2014) compiled guidelines from researchers for interpreting Bayes Factors and report that BFs of 1–3 indicate anecdotal or weak evidence for the hypothesis, BFs of 3–10 indicate substantial evidence, and BFs >10 indicate strong evidence for the given hypothesis. BFs were calculated in JASP (JASP Team, 2020). For the three-way interaction, the BF_{01} was 6.57, which indicates substantial evidence for the null hypothesis. Specifically, this means that the data were 6.57 times more likely under the null

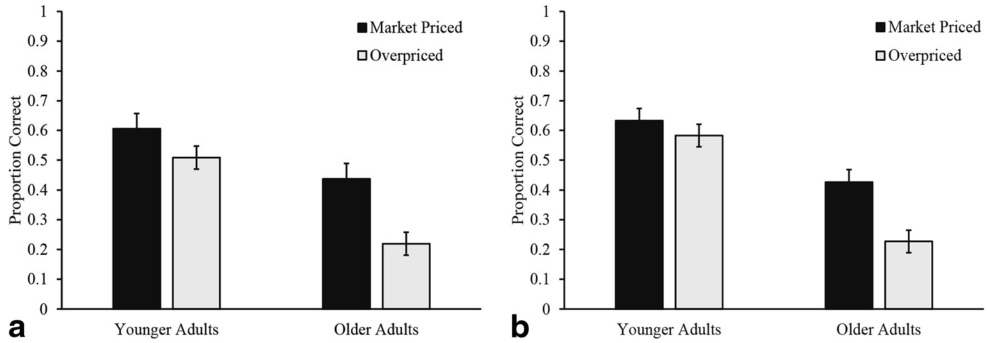

Fig. 1 Average proportion of correct price recall in Experiment 1 (**A**, left panel) and Experiment 2 (**B**, right panel) as a function of age group and price type collapsed across all four lists. Error bars represent standard error of the mean

hypothesis than under the alternative hypothesis. The main effect of list had a BF_{01} of 9.58, and the interaction of list and age had a BF_{01} of 23.65. For subsequent ANOVA analyses, BF_{01} will be reported for null effects.

Confidence To assess differences in confidence by age, item price, and list, we conducted a 2 (Price: market-priced, overpriced) × 4 (List) × 2 (Age: younger adults, older adults) mixed ANOVA, with price and list as within-subjects variables and age as a between-subjects variable on confidence rating (ranging from 1 to 7). We found that overpriced items were given lower confidence ratings (M = 4.37, SD = 1.00) than market-value items (M = 4.74, SD = 1.12), $F(1, 46) = 16.72$, $p < .001$, $\eta_p^2 = 0.27$. In addition, younger adults (M = 4.87, SD = 1.44) gave higher confidence ratings than older adults (M = 4.23, SD = 1.44), $F(1, 46) = 4.79$, $p = .03$, $\eta_p^2 = 0.09$. However, the main effect of list was not significant, $F(3, 138) = 1.23$, $p = .30$, $\eta_p^2 = 0.03$, $BF_{01} = 13.74$. In addition, age did not interact with price type, $F(1, 46) = 3.45$, $p = .07$, $\eta_p^2 = 0.07$, $BF_{01} = 0.82$, or with list, $F(3, 138) = 1.46$, $p = .23$, $\eta_p^2 = 0.03$, $BF_{01} = 4.35$, and the interaction between price type and list was not significant, $F(3, 138) = 0.80$, $p = .50$, $\eta_p^2 = 0.02$, $BF_{01} = 17.46$. Lastly, the three-way interaction was not significant, $F(3, 138) = 0.32$, $p = .81$, $\eta_p^2 = 0.01$, $BF_{01} = 17.06$. Because the BF for the age-price type interaction was less than 1, we cannot effectively tease apart whether there is evidence for or against the interaction. The effect was likely small, and we may be underpowered to detect it. However, the pattern of mean confidence ratings matches that of recall performance.

Study time Figure 2 shows average study time, in seconds, as a function of age group, price type, and list. To assess how study time was affected by age, price, and list, we ran a 2 (Price: market-priced, overpriced) × 4 (List) × 2 (Age: younger adults, older adults) mixed ANOVA with study time, measured in seconds, as the outcome. The analysis revealed a significant main effect of list, $F(3, 138) = 6.17$, $p < .001$, $\eta_p^2 = 0.12$. A post hoc trend analysis of the list variable revealed a significant quadratic trend, $F(1, 46) = 11.90$, $p = .001$, $\eta_p^2 = .21$, indicating that items were studied longer on intermediate lists than items on earlier and later lists. The main effect of price was also significant, $F(1, 46) = 5.69$, $p = .02$, $\eta_p^2 = 0.11$, such that overpriced items (M = 6.67 s, SD = 3.81 s) were studied longer than market-priced items (M = 5.89 s, SD = 3.38 s), but the main effect of age was not significant, $F(1, 46) = 0.06$, $p = .81$, $\eta_p^2 = .001$, $BF_{01} = 3.01$. In addition, neither the interaction of price and list, $F(2.18, 100.49) = 1.01$, $p = .39$, $\eta_p^2 = 0.02$ $BF_{01} = 14.09$, list and age, $F(3, 138) = 0.83$, $p = .48$, $\eta_p^2 = 0.02$ $BF_{01} = 12.37$, nor price and age, $F(1, 46) = 1.02$, $p = .32$, $\eta_p^2 = 0.02$ $BF_{01} = 3.69$ were significant, and the three-way interaction was not significant, $F(2.18, 100.49) = 0.68$, $p = .57$, $\eta_p^2 = 0.02$, $BF_{01} = 8.78$.

To assess the influence of study time on memory performance, we used a mixed effects logistic regression model, also known as a multilevel or hierarchical model. A multilevel approach was used for a couple of reasons. First, treating all predictors as belonging to a single level treats observations as independent, even though they are repeated within participants. In addition, there may be meaningful variability across participants in study time that are not accounted for using other statistical methods (Baayen et al., 2008; Murayama et al., 2014). This method is also increasingly being used because of its ability to capture both within-participant and between-participant variability (Castel et al., 2013b; Middlebrooks & Castel, 2018; Siegel & Castel, 2019; Vuorre & Bolger, 2018).

We hypothesized that study time might mediate the relationship between price-type and recall performance at the item level, suggesting that the price category of an item influences how long an item would be studied, which may then influence the likelihood of correctly recalling the price of the item. Specifically, if market-value items were studied longer, this extra study time may explain some of the relationship between price type and later recall. Alternatively, if more difficult items were studied longer, memory for those items may be improved as a result of extra study time. This would result in a decreased effect of price type on memory performance when controlling for study time, otherwise known as suppression (see MacKinnon et al., 2000). Figure 3 depicts the mediation model with path coefficients. Item-level recall accuracy was

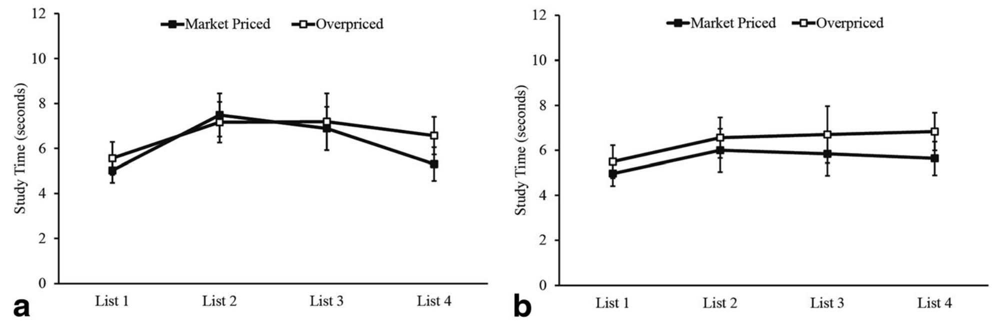

Fig. 2 Average study time as a function of price type and list for younger adults (**A**, left panel) and older adults (**B**, right panel) in Experiment 1. Error bars represent standard error of the mean

modeled logistically because of its binary nature (i.e., 0 = incorrect, 1 = correct), whereas the mediator, study time, was continuous and was standardized before analyses, consistent with recommendations (Mackinnon & Dwyer, 1983; Winship & Mare, 1993). We treated items as clustered within participants, so that Level 1 indicated items and Level 2 indicated participants. All variables in the mediation model (e.g., price, study time, and recall) were Level 1 variables. The main predictor variable, price type, was dichotomous and anchored on overpriced items.

For the analysis, we used a Bayesian approach, which has benefits for estimation with a dichotomous outcome and allows for a more straightforward estimation of multilevel mediation using Markov chain Monte Carlo (MCMC), rather than traditional ordinary least squares or maximum likelihood estimation (see Vuorre & Bolger, 2018, for an in-depth discussion of the benefits). All mixed-effects models were estimated in *R* (R Core Team, 2020) using the *bmlm* package (Vuorre, 2017; see Vuorre & Bolger, 2018). Because of the MCMC estimation method, the path coefficients are presented with 95% confidence intervals (CIs) rather than typical inferential statistics, like *z* tests or *p* values. In addition, the path coefficients are reported here using symbols consistent with mediation analyses, wherein the path from the predictor to the mediator is indicated by *a*, the path from the mediator to the outcome is *b*, the path from the predictor to the outcome controlling for the mediator is *c'*, and the total effect, *c*, indicating the path from the predictor to the outcome without controlling for the mediator. Lastly, we refer to the overall indirect effect (the product of *a* and *b*) as simply the "mediated effect."

Because the effect of age on study time was not significant, we first collapsed across age groups for the mediation analysis. First, the model showed that item price was a significant predictor of recall without controlling for study time ($c = 0.82$, CI: 0.50–1.14). The model also revealed that item price did predict study time ($a = -0.11$, CI: -0.18 – -0.03), such that market-value items were studied for less time than overpriced items. However, study time did not significantly predict later price recall accuracy ($b = 0.02$, CI: -0.13–0.17), and item price remained a significant predictor of recall while controlling for study time ($c' = 0.82$, CI: 0.50–1.14). Further, the overall

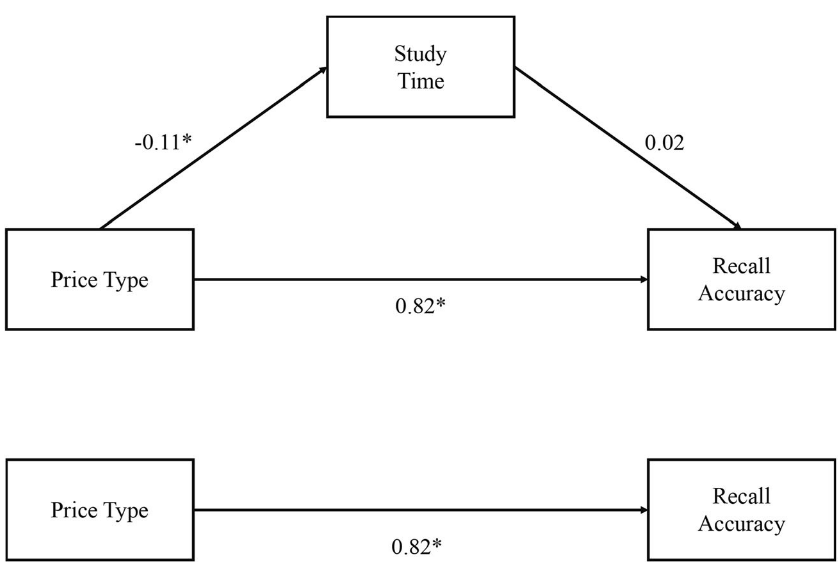

Fig. 3 Mediation analysis showing relationship between price type (anchored on overpriced items), study time (which was standardized), and likelihood of correct recall. Coefficients are shown in standardized units. *Note:* * indicates the confidence interval did not include zero

mediated effect was not significant (mediated effect = 0.00, CI: -0.02–0.02).

To better understand these effects for younger and older adults, we next ran the same mediation model for younger and older adults separately, although any differences between age groups should be interpreted with caution, as there were no significant age effects on study time and we lose some power by restricting the age group. For younger adults, the effect of price type on study time was not significant (a = -0.08, CI: -0.19–0.04), and study time did not significantly predict recall performance (b = -0.01, CI: -0.28–0.22). The effect of price type on recall performance was significant without controlling for study time (c = 0.57, CI: 0.08–1.07), and price type remained significant while controlling for study time (c' = 0.56, CI: 0.08–1.07), meaning that prices of market-value items were better recalled than those of overpriced items when controlling for the effects of study time. The test of the indirect effect showed that study time was not a significant mediator of the relationship between price type and later recall (mediated effect = 0.00, CI: -0.03–0.04).

However, for older adults, price type was a significant predictor of study time (a = -0.14, CI: -0.24 – -0.03), indicating overpriced items were studied longer than market-value items. However, study time did not significantly predict recall accuracy (b = 0.03, CI: -0.22–0.26), and the effect of price type on recall accuracy was significant without controlling for study time (c = 1.09, CI: 0.70–1.47) and controlling for study time (c' = 1.09, CI: 0.70–1.47). In addition, study time did not significantly mediate the relationship between price type and recall performance (mediated effect = 0.00, CI: -0.04 – 0.03). Thus, although older adults did study items for different amounts of time depending on their price type, this study time did not influence their memory. Of note, we should be careful interpreting the differences between younger and older adults as these were not directly tested.

Experience Lastly, we assessed participants' performance in relation to their frequency of grocery shopping and experience buying each item, which can serve as another measure of schematic support at the individual level. First, we conducted a logistic multilevel model with recall accuracy modeled as a function of age, price type, and their interaction, as well as the participant-level shopping frequency variable and its interaction with price type and age. The analysis revealed that age, price, and the interaction of age and price remained significant predictors of the likelihood of correct recall at the item level. Additionally, the frequency of shopping was a significant predictor of recall (e^B = 2.18, CI: 1.41–3.39, z = 3.49, $p < .001$), and the interaction between shopping frequency and age was significant (e^B = 0.44, CI: 0.237–0.832, z = -2.54, p = .01). Follow-up analyses showed that greater frequency of grocery shopping was predictive of greater likelihood of correct recall in younger adults (e^B = 2.18, CI: 1.41–3.39, z = 3.49, $p <$ .001), but not in older adults (e^B = 0.97, CI: 0.62–1.52, z = -0.13, p = .90). Thus, younger adults who grocery shop more frequently performed better on the task than those who shopped less frequently. Older adults (M = 4.16, SD = 0.90) did report grocery shopping more often than younger adults (M = 3.33, SD = 0.82) overall, $t(41)$ = 3.15, p = .003, d = 0.97. However, although these questions were asked post hoc and were not answered by all participants, these results are inconsistent with the idea that older adults' performance can be explained by greater grocery shopping experience.

Additionally, we asked participants to report which items they typically buy and at what price. We ran a model predicting accuracy at the item level from the item's price, whether the participant reported buying the item, age, and the interaction of each of these factors, which showed that age, price, and the interaction between age and price were significant, and that buying the item was related to better recall, e^B = 1.96, CI: 1.197–3.191, z = 2.68, p = .007, but did not interact with other factors (all ps > .77). Notably, these questions were asked after the experiment and some participants did not answer the questions or may have misunderstood the directions, but the results are consistent with the finding that schematic support, even at the individual level, benefits memory.

Discussion

In Experiment 1, we found that younger adults showed more accurate recall for the prices of overpriced items but did not show better recall for market-value prices, consistent with findings from Castel (2005). In addition, we did not find age differences in the amount of time participants studied items, but in general participants studied overpriced items longer, consistent with the discrepancy reduction hypothesis of self-regulated learning. The results were inconsistent with a meaningfulness account.

In addition, study time did not influence the likelihood of correctly recalling the prices, suggesting a labor-in-vain effect for both younger and older adults. Participants may not have engaged in effective encoding strategies in order to improve memory for the unusual prices, or participants studied the items longer than was needed to achieve the same level of memory performance. Of note, there were new items on each list, which may have made it more difficult to improve memory for difficult items. In general, however, it seems that schematic support may benefit memory independent of the influence of metacognitive control processes.

As with any research on self-paced study time, there are some limitations in the use of study time to measure metacognitive control processes and in then inferring what cognitive operations occur during this self-paced study-time allocation. In the current study, study time was highly skewed and the range of average study time was fairly large. However, trimming the data to exclude extreme study-time values (beyond 3.5 standard deviations) did not influence the pattern of results. In Experiment 2 we further examined the role of metacognition by having participants make judgments of learning during encoding.

Experiment 2

In Experiment 1, older adults recalled more market-value prices than unusual prices but studied the overpriced items longer. However, it can be argued that, rather than monitoring influencing control, metacognitive control processes can also influence monitoring (see Koriat et al., 2006). In other words, studying the item longer may have led participants to feel as though it was more difficult, and this feeling of difficulty was related to memory performance. Therefore, in Experiment 2, we examined metacognitive awareness of schematic support without the influence of self-paced study. We were interested in age differences in metacognitive judgments and memory performance for items with and without schematic support. Participants made JOLs at encoding and, as in Experiment 1, made confidence judgments at retrieval. We also tested gist memory and confidence in gist performance. Gist memory, or memory for the general category (e.g., overpriced or market value) as opposed to verbatim memory (e.g., the exact amount of the item), has been shown to be intact in older adults (see Castel, 2005;Flores et al., 2017 ; Gallo et al., 2019). This measure can also be thought of as source memory, or memory for the contextual information that was presented during learning, but we refer to it as gist memory, which is consistent with prior work (Flores et al., 2017; Gallo et al., 2019). Additionally, the price category was not explicitly presented with the items during study but was inferred based on the exact price of each item, so we were interested in whether people have a more general memory for the item's price in addition to more specific memory for the price. We also sought to extend prior work regarding gist memory by examining participants' confidence judgments related to gist performance.

Method

Participants Younger adult participants (n = 24) were UCLA undergraduates aged 18–25 years (M = 20.08, SD = 1.56; 19 females) who received course credit for their participation. Older adult participants (n = 24) were 61–85 years old (M = 68.79, SD = 5.87; 12 females) and received $10 per hour for their participation. Older adult participants came to the lab independently, reported being in good health, and wore corrective lenses if needed. As with Experiment 1, older adults had a forward digit span score of at least four and did not report any diagnosed cognitive decline.

Materials and procedure The materials were identical to those used in Experiment 1. The procedures were similar to that of Experiment 1 except that rather than self-pacing study of each grocery item, items were presented with their prices for 10 s each, similar to Castel (2005). Procedures were approved by the UCLA IRB. Participants were told that they would study four lists of grocery items (some market-priced and some overpriced), which would appear for 10 s each. Participants were instructed to try to remember the exact price of each item. Like in Experiment 1, participants were informed that all items ended in 9 and that meat and produce items were priced per pound.

Participants studied each item, and then rated on a 100-point scale from 0 (*not at all likely*) to 100 (*very likely*) how likely they would be to remember the exact price of the item on a later test. JOLs were made without the image of the item present. After each test trial, participants made confidence ratings in their answer on a scale from 1 (*not at all confident*) to 7 (*very confident*). Participants then made gist responses by reporting whether the item was market-priced or overpriced (see Castel, 2005) and rated their confidence in their response. After all four lists, participants listed the items they typically buy and the price they pay for those items, as well as how often they did their grocery shopping. Finally, participants were asked to report any strategy they used to try to remember the prices of the items they studied, and this question was open-ended.

Results

Memory performance Figure 1B shows average proportion of correct recall by age group and price type. To first examine cued recall performance as a function of price, list, and age, we conducted a 2 (Price: market, over) × 4 (List) × 2 (Age: young, old) repeated-measures ANOVA on the proportion of correctly recalled prices. The analysis revealed the main effect of price was significant, such that market-value prices (M = .53, SD = .20) were better remembered than the prices of overpriced items (M = .41, SD = .19), $F(1, 46) = 19.38$, $p < .001$, $\eta_p^2 = 0.30$. In addition, the main effect of list was significant, $F(3, 138) = 3.39$, $p = .02$, $\eta_p^2 = 0.07$. Follow-up tests revealed a significant quadratic trend, $F(1, 46) = 4.43$, $p = .04$, $\eta_p^2 = .09$, such that items were better remembered on the first list than on subsequent lists. The main effect of age was also significant, such that younger adults (M = .61, SD = .24) were overall more accurate than older adults (M = .33, SD = .24), $F(1, 46) = 35.05$, $p < .001$, $\eta_p^2 = 0.43$.

There was also a significant interaction between price and age, $F(1, 46) = 6.98$, $p = .01$, $\eta_p^2 = 0.13$. Follow-up t-tests with Bonferroni corrections revealed that older adults showed lower recall than younger adults for both market prices (M_{young} = .63, SD_{young} = .28; M_{older} = .43, SD_{older} = .28), $t(75) = 3.73$, $p = .002$, and unrealistic prices (M_{young} = .58, SD_{young} = .26; M_{older} = .23, SD_{older} = .26), $t(75) = 6.44$, $p <$ .001, but the age difference was greater for overpriced items than for market-priced items. List did not significantly interact with price type, $F(3, 138) = 2.52$, $p = .06$, $\eta_p^2 = 0.05$, BF_{01} = 2.19, or with age, $F(3, 138) = 1.94$, $p = .13$, $\eta_p^2 = 0.04$, BF_{01} = 5.37. Thus, neither the effect of price nor age significantly changed with increased task experience. Lastly, the interaction between price, list, and age was not significant, $F(3, 138)$ = 0.46, $p = .71$, $\eta_p^2 = .01$, BF_{01} = 11.82.

We next examined gist accuracy with a similar 2 (Price: market, over) × 4 (List) × 2 (Age: young, old) ANOVA on the proportion of correctly categorized items (i.e., as either market-priced or overpriced). This revealed the main effect of price was significant, $F(1, 46) = 15.17$, $p < .001$, η_p^2 = 0.25, such that participants correctly categorized a greater proportion of market-priced items (M = .87, SD = .13) than overpriced items (M = .76, SD = .13). However, the main effect of list was not significant, $F(3, 138) = 2.31$, $p = .08$, $\eta_p^2 = 0.05$, BF_{01} = 7.83, nor was the main effect of age, $F(1, 46) = 0.42$, $p = .52$, $\eta_p^2 = 0.01$, BF_{01} = 5.02. In addition, age did not interact with price, $F(1, 46) = 0.29$, $p = .60$, $\eta_p^2 = 0.01$, BF_{01} = 5.00, or with list, $F(3, 138) = 0.54$, $p = .66$, $\eta_p^2 = 0.01$, BF_{01} = 22.57. The interaction between price and list was also nonsignificant, $F(3, 138) = 0.60$, $p = .61$, $\eta_p^2 = 0.01$, BF_{01} = 18.42, and the three-way interaction was not significant, $F(3, 138) = 0.74$, $p = .53$, $\eta_p^2 = 0.02$, BF_{01} = 7.71.

Metacognitive judgments Average JOLs across price type, age group, and list are shown in Fig. 4. To assess the influence of price type, age group, and list on JOLs, we conducted another repeated-measures ANOVA on JOLs. Two participants were removed from this analysis due to not following directions for the JOL portion of the task only. The analysis revealed that the main effect of price was significant, $F(1, 44)$ = 7.29, $p = .01$, $\eta_p^2 = 0.14$, such that market prices (M = 56.75, SD = 22.15) were judged as more likely to be remembered than the prices of overpriced items (M = 52.82 SD = 21.29). In addition, the main effect of list was significant, $F(1.95, 85.75)$ = 8.12, $p < .001$, $\eta_p^2 = 0.16$, and follow-up tests showed there was a significant negative linear trend, such that JOLs decreased across lists, $F(1, 44) = 12.60$, $p = .001$, $\eta_p^2 = 0.22$. However, the main effect of age was not significant, $F(1, 44)$ = 2.01, $p = .16$, $\eta_p^2 = 0.04$, BF_{01} = 1.26. In addition, age did not significantly interact with price, $F(1, 44) = 1.51$, $p = .23$, $\eta_p^2 = .03$, BF_{01} = 1.67, or with list, $F(1.95, 85.75) = 0.49$, p = .61, $\eta_p^2 = 0.01$, BF_{01} =17.71, and the interaction between list and price was not significant, $F(3, 132) = 1.14$, $p = .34$, η_p^2 = 0.03, BF_{01} = 14.79. Lastly, the three-way interaction was not significant, $F(3, 132) = 0.78$, $p = .51$, $\eta_p^2 = 0.02$, BF_{01} = 9.81. Thus, it seems participants were aware of the differences in difficulty between overpriced and market-priced items and the increased difficulty across lists, but older adults did not rate their ability to remember items significantly differently from that of younger adults. Of note, however, BFs for the age main effect and age-price interaction are considered anecdotal, so the age effects on JOLs are inconclusive.

As another measure of metacognitive judgments, we also assessed confidence ratings, which were made on a 1–7 scale. We conducted a 2 (Price: market, over) × 4 (List) × 2 (Age: young, old) mixed ANOVA on confidence ratings and found that market-value prices (M = 4.93, SD = 1.13) were given significantly higher confidence ratings than unusual prices (M = 4.42, SD = 1.10), $F(1, 46) = 28.11$, $p < .001$, $\eta_p^2 = 0.38$. In addition, younger adults (M = 5.29, SD = 1.50) gave higher confidence ratings than older adults (M = 4.06, SD = 1.50), $F(1, 46) = 16.00$, $p < .001$, $\eta_p^2 = 0.26$. The interaction between price and age was also significant, $F(1, 46) = 4.97$, $p = .03$, $\eta_p^2 = 0.10$, and follow-up Bonferroni-corrected t-tests revealed that younger adults' confidence ratings were not significantly different for overpriced (M = 5.14, SD = 1.60) and market-value prices (M = 5.44, SD = 1.56), $t(46) = 2.17$, $p = .21$, but older adults gave significantly lower confidence ratings for overpriced items (M = 3.69, SD = 1.60) than market prices (M = 4.43, SD = 1.56), $t(46) = 5.33$, $p < .001$.

The main effect of list was not significant, $F(2.24, 102.97)$ = 0.66, $p = .53$, $\eta_p^2 = 0.01$, BF_{01} = 32.65, and list did not significantly interact with age, $F(2.24, 102.97) = 1.13$, $p = .33$,

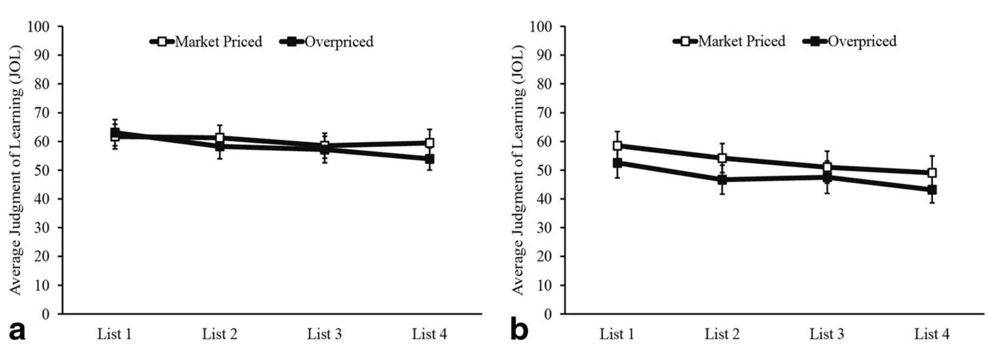

Fig. 4 Average judgments of learning (JOL) for market-priced and overpriced items across all four lists for younger adults (**A**, left panel) and older adults (**B**, right panel) in Experiment 2. Error bars represent standard error of the mean

$\eta_p^2 = 0.02$, $BF_{01} = 7.83$, or with price, $F(2.82, 129.67) = 2.35$, $p = .08$, $\eta_p^2 = 0.05$, $BF_{01} = 5.43$. Lastly, the three-way interaction was not significant, $F(2.82, 129.67) = 0.09$, $p = .96$, $\eta_p^2 = 0.002$, $BF_{01} = 14.51$. We also examined confidence ratings for the gist questions, but no significant effects emerged (all Fs < 1.13, all ps > .34, all $BF_{01} > 2.13$), so the analyses are not reported here.

To assess the extent to which participants were metacognitively aware of the effects of price type on later recall performance, we conducted a mediation analysis with price type as the main predictor, JOL as the mediator, and recall performance as the outcome. If JOLs mediated the relationship between price type and recall accuracy, it would indicate that the price type of an item influences one's JOL, which is then related to memory performance. In other words, it would indicate an awareness of the influence of price type on memory.

The mediation model with path coefficients is presented in Fig. 5. As in the study time model in Experiment 1, we treated the data as multilevel and used a Bayesian approach for the mediation analysis. We also collapsed across age groups for the initial analysis. First, the model showed that price type was a significant predictor of accuracy without controlling for JOLs ($c = 0.66$, CI: 0.35–0.98). The model also revealed that price type did significantly predict JOL ($a = 0.14$, CI: 0.04–0.24), such that market-value items were given higher JOLs than overpriced items. In addition, JOLs did significantly predict accuracy ($b = 0.77$, CI: 0.57–0.99), indicating that items given higher JOLs had a higher likelihood of later being remembered. The effect of price type on memory performance remained significant while controlling for JOLs ($c' = 0.55$, CI: 0.25–0.84). Of most interest, the overall mediated effect was significantly different from zero (mediated effect = 0.11, CI: 0.03–0.21). Thus, JOLs did account for some of the variation in the relationship between item price and later recall, indicating participants were generally metacognitively aware of the increased difficulty of remembering arbitrary information.

We again broke the model down for younger and older adults, but as with Experiment 1, these results should be interpreted with caution, as the age effects on JOLs were not significant. For younger adults, price type was not a significant predictor of JOLs ($a = 0.08$, CI: -0.07–0.22) or of accuracy without controlling for JOLs ($c = 0.33$, CI: -0.08–0.74). Price type also did not significantly predict recall performance while controlling for JOLs ($c' = 0.24$, CI: -0.14–0.61). However, JOLs were a significant predictor of recall accuracy ($b = 0.91$, CI: 0.58 – 1.28). Lastly, JOLs were not a significant mediator of the relationship between price type and later recall, (mediated effect = 0.09, CI: -0.07–0.27).

For older adults, price type was a significant predictor of accuracy overall ($c = 0.97$, CI: 0.50–1.42) and of JOLs ($a = 0.20$, CI: 0.11–0.29), such that market-value items were given higher JOLs than overpriced items. Additionally, higher JOLs were related to a greater likelihood of correct recall ($b = 0.69$, CI: 0.42–0.98), and the effect of price type on recall performance remained significant while controlling for the influence of JOLs ($c' = 0.83$, CI: 0.37–1.27). Lastly, for older adults, JOLs did mediate the relationship between price type and recall accuracy (mediated effect = 0.14, CI: 0.06–0.24). This finding suggests that older adults were aware of the influence of price type on memory performance and made JOLs in line with performance.

Experience Lastly, we assessed whether participants' reported frequency of grocery shopping was related to the benefit of schematic support on memory performance. We ran a

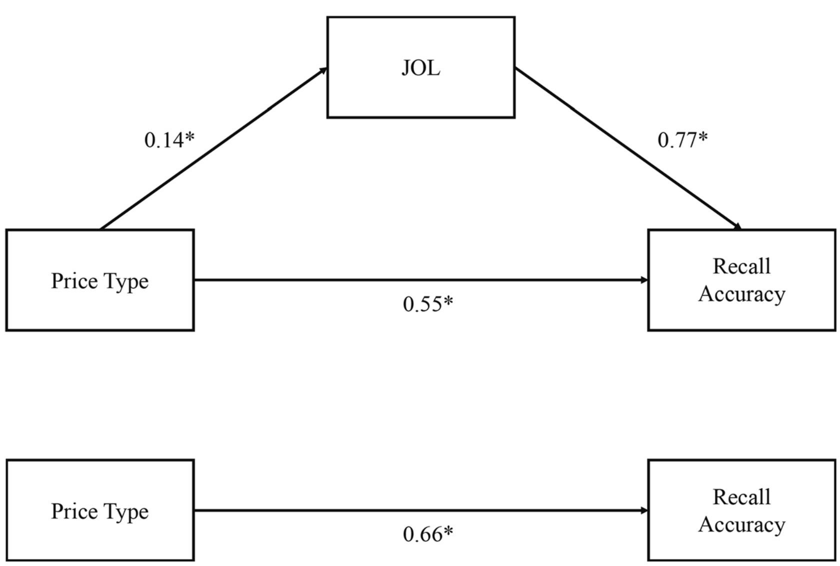

Fig. 5 Mediation model showing the relationship between price type (anchored on overpriced items), judgment of learning (which was standardized), and likelihood of correct recall. *Note:* * indicates the confidence interval did not include zero

multilevel model with age, price, frequency of shopping, and the interaction of these factors as predictors of item-level accuracy. Age, price type, and their interaction all remained significant predictors of memory accuracy. Shopping frequency, however, was not a significant predictor of recall (e^B = 1.03, CI: 0.64–1.66, $z = 0.11$, $p = .91$), and shopping frequency did not interact with age or price type (all $ps \geq .07$).

To further explore the relationship between schematic support and memory performance, we also ran a multilevel logistic model with recall accuracy as a function of age, price type, and whether the participant marked the item as one they typically buy or not, as well as all two-way interactions of these factors. The age-price interaction was still significant. The interaction between age and buying the item was not significant (e^B = 1.30, CI: 0.84–2.03, $z = 1.17$, $p = .24$), but the interaction between price type and buying the item was significant (e^B = 0.54, CI: 0.36–0.82, $z = 2.90$, $p = .004$). Follow-up tests using Bonferroni corrections revealed that when the item was not one the participant typically purchased, the likelihood of correctly recalling the price did not differ between market value and overpriced items (e^B = 0.76, CI: 0.56 – 1.04, $z = 1.73$, $p = .50$). However, when the item was one that was typically purchased, prices of market-value items were remembered significantly better than those of overpriced items (e^B = 0.41, CI: 0.32–0.55, $z = 6.30$, $p < .001$). Thus, when both younger and older adults had schematic support at the item level (in the form of prior knowledge about the item), they benefitted from seeing market-value items, but this was not the case when participants did not have prior knowledge about the item and its general price. Of note, this finding was not replicated in Experiment 1, and these questions were asked post hoc and some participants did not answer them. Thus, while interesting, these questions may be more interesting for future research to examine, including whether the extent to which schematic support affects memory can be influenced by one's goals.

Discussion

In Experiment 2, we again found that older adults were able to better remember market-value prices than unusual prices. However, in this experiment, older adults' memory for market-value prices did not reach that of younger adults, unlike in Experiment 1 and in Castel (2005). One explanation for this finding is JOL reactivity. Some work has found that the act of making a JOL can influence later memory performance (Kimball & Metcalfe, 2003; Soderstrom et al., 2015; Spellman & Bjork, 1992), also in line with the "monitoring affects control" view (see Koriat et al., 2006). However, recent work shows that JOLs do not influence memory for older adults (Tauber & Witherby, 2019) and that the effect of JOL reactivity often only appears with related materials and the effects are fairly small (Double et al., 2018). The act of making JOLs may have improved younger adults' memory performance, but not that of older adults, leading to greater age differences in Experiment 2.

We also found that JOLs in Experiment 2 showed a similar pattern as study time from Experiment 1. Specifically, there were no significant age differences or interactions with age on JOLs, but participants were sensitive to differences in price type and they varied across lists in the same manner. Thus, participants' monitoring judgments in Experiment 2 were in line with the study time (i.e., metacognitive control) findings from Experiment 1. Additionally, JOLs mediated the relationship between price type and the likelihood of later recalling the price of the item. In other words, JOLs accounted for some of the variation in this relationship, indicating that participants were generally aware of the differences in difficulty between the two item types.

Lastly, we found that the extent to which one had schematic support for an item moderated whether they benefited from seeing the price at market value as compared to overpriced. This suggests that younger and older adults can benefit from prior knowledge about an item's general price, and that participants rely on schematic support at the item level.

General discussion

Schematic support has been shown to facilitate associative memory performance, especially in older adults who face reduced cognitive resources (Castel, 2005; Castel et al., 2013a; Kuhns & Touron, 2019). However, it is not known whether memory for schema-consistent or inconsistent information can be influenced by metacognitive control processes, including self-paced study time, or whether participants are aware of the benefits of schematic support on memory. From a theoretical perspective, the ability to influence associative memory performance by selectively allocating more study time and, therefore, more cognitive resources to information consistent or inconsistent with prior knowledge would suggest that schematic support may be a product of – or at least influenced by – strategic encoding processes.

Results from Experiment 1 demonstrated that when given the opportunity to self-pace study of grocery items and prices that were either consistent (market value) or inconsistent (overpriced) with prior knowledge, older and younger adults adopted a similar study strategy: participants studied overpriced items longer than market-priced items, and this did not differ by age group. In Experiment 2, overpriced items were also judged as less likely to be remembered than market-value items at encoding, and again there were no significant age differences in JOLs. Thus, participants in general seem to be metacognitively aware of the benefits of schematic support.

Confidence ratings also supported the finding that participants were sensitive to differences in difficulty between price categories. Overpriced items received lower confidence ratings than market-value items in both experiments. Unlike with JOLs and study time, however, we did find significant age differences in confidence judgments in both experiments. Older adults gave lower confidence ratings overall, and age interacted with price type in Experiment 2. Importantly, confidence judgments reflect participants' confidence in their responses, rather than giving a measure of how difficult participants perceived the item to be. Because confidence judgments are made after recall, they tend to rely on and measure a different construct than JOLs (see Rhodes, 2016). In addition, because participants have greater access to their memories after retrieval, confidence judgments may be more accurate (Siedlecka et al., 2016). Indeed, the confidence ratings more closely resembled recall performance than JOLs or study time in the current experiments. Thus, at encoding and at retrieval, participants were sensitive to the differences in memory for realistic and arbitrary information.

Of note, the sample sizes in the current experiments were fairly small, and we obtained enough power to detect small-to-medium effect sizes, but may have lacked power to detect smaller effects. Sample size was consistent with some prior literature on this topic (e.g., Flores et al., 2017; Mohanty et al., 2016), but the small sample size is a limitation in this study and future work should include larger samples when studying these factors.

In Experiment 1, the finding that participants studied overpriced items longer than market-value items is consistent with the discrepancy reduction model, which posits that more difficult items should be studied longer in order to reduce the discrepancy between the current and desired level of memory performance (Dunlosky & Hertzog, 1998b). We hypothesized that older adults may allocate more study time to remember realistic information because it is more meaningful or important, as suggested by some prior work (Artuso et al., 2020; Castel et al., 2013b; Fung et al., 2018). However, older adults may not need additional study time to engage in a form of meaningful processing. In a related study (Castel et al., 2013a), older adults remembered prices from the past that fit with prior knowledge (e.g., movie ticket $2.00) better than future-based item-price pairs (e.g., robot maid $1,600), suggesting that prior knowledge and schemas help older adults remember meaningful prices.

These findings are inconsistent with the possibility that participants (especially older adults) were less motivated to remember the more difficult or arbitrary associative pairs. In fact, one could argue that both younger and older adults were *more* motivated to remember the arbitrary pairs, assuming that allocating study time is indicative of motivation. Work that has examined the influence of motivation on cognitive engagement in older adults has found that older adults are often more selective in choosing information to allocate cognitive effort towards both between separate tasks and between easier and difficult items within an individual task (see Hess, 2014; Whatley et al., 2021). The lack of age differences in study time and increased study time for more difficult items suggests that older adults were not less motivated than younger adults in this study, and therefore, age-related differences in motivation did not contribute to the current memory findings.

Most surprising was the finding that study time was not related to recall accuracy for either younger or older adults, which may support a labor-in-vain hypothesis (Nelson & Leonesio, 1988); despite greater time spent studying overpriced items, participants did not get a corresponding benefit in recall performance. In line with previous studies (e.g., Amer et al., 2018; Castel, 2005; Mohanty et al., 2016), older adults remembered the exact prices of market-priced items better than overpriced items when able to control study time, suggesting that older adults benefit from schematic support independent of metacognitive control processes.

There are a few potential explanations for why study time did not influence accuracy. Given that older adults do not often spontaneously engage in effective strategy use (Bouazzaoui et al., 2010; Dunlosky & Hertzog, 1998a; Rogers et al., 2000), older adults may not have adopted more effective encoding strategies to help them remember the overpriced items during extra study time. This, in turn, may have contributed to the age-related difference in memory performance, despite similar study time. However, there was no relationship between study time and recall accuracy for either age group. Perhaps younger adults also failed to engage in effective strategy use or did not need the extra study time to reach a higher level of performance. The labor-in-vain hypothesis proposes that participants study items longer than is needed to achieve a desired level of performance, so younger adults may have simply overstudied. One might also hypothesize that if older adults regulate their study time, they might benefit from additional time to compensate for general slowing of encoding processes, but the present results do not suggest that additional study time helps older adults in this task.

On the other hand, the finding that study time did not influence the likelihood of correct recall could indicate that schematic support facilitates faster, easier encoding of stimuli that are consistent with prior knowledge and does not depend on metacognitive control processes. This explanation is supported by prior work that shows schematic support may reduce processing demands at encoding via the activation of schemas (Besken & Gülgöz, 2009; Gilboa & Marlatte, 2017). This schema activation likely leads to an easier acquisition of information, independent of any motivational or metacognitive processes. It is worth noting that younger adults did not show differences in memory performance between market-priced and overpriced items. Thus, perhaps older adults, more so than younger adults, are reliant on schema-dependent processing and receive less of a benefit from metacognitive control processes when study is self-paced.

In this task, participants were presented with new items on each list, unlike some previous studies in which participants have studied the *same* items across multiple study-test lists (e.g., Mazzoni et al., 1990; Mazzoni & Cornoldi, 1993). The ability to improve metacognitive control across multiple lists with new items served more as a test of transfer of metacognitive abilities, and participants may have shown improved performance if shown the same items across lists. However, participants have been shown to improve metacognitive monitoring abilities across lists with new items (e.g., McGillivray & Castel, 2017).

The finding that schematic support may occur independently of strategic metacognitive control processes further supports the idea that episodic and semantic memory are less clearly differentiated than has been previously thought. In this task, participants learned new associations across four study-test lists, each with new items (an episodic memory task). The presumed activation of prior knowledge about grocery prices (e.g., semantic memory) bolstered memory performance for items that fit more easily with that prior knowledge. Thus, it is clear that episodic and semantic memory are certainly not working separately or independently in this task, and they may be even more reliant on one another in older age.

Open practices statement The datasets generated during the current research are available from the corresponding author upon reasonable request. These experiments were not preregistered.

Author note The authors have no conflicts of interest to declare.

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