Reactivity from Judgments of Learning are not due to Judgments of Learning:

Evidence for a Strategic Relational Encoding Account

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Abstract

Research has shown that judgments of learning (JOLs) often produce a reactive effect on learning of cue-target pairs in which target recall differs between participants who provide JOLs at study versus those who do not. Positive reactivity, or the memory improvement found when JOLs are provided, is typically observed on related pairs, whereas negative or no reactivity has been found on unrelated pairs. In four experiments, we examined JOL reactivity effects by comparing JOL and no-JOL groups to other groups who engaged in relational-type encoding tasks. Experiment 1 replicated positive JOL reactivity effects with related pairs with an extension to symmetrically related pairs. In Experiment 2, a similar positive reactivity pattern was found using a relational encoding task when compared to a standard JOL Next, Experiment 3 found that providing judgments of associative memory—a task that does not provide memory predictions—yielded equivalent reactivity patterns as JOLs. Finally, Experiment 4 replicated this reactivity pattern using a frequency-judgment task. Collectively, our results suggest that previous JOL reactivity patterns are not due to memory forecasting processes using JOLs and instead reflect relational encoding that is strategically directed towards related, but not unrelated pairs.

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Reactivity from Judgments of Learning are not due to Judgments of Learning:

Evidence for a Strategic Relational Encoding Account

An individual’s ability to accurately monitor the progress of their own learning is a critical component for successful retention. Effective monitoring allows individuals to adjust their study strategies to maximize memory performance (Nelson & Narens, 1990) and provides insights on how best to allocate memorial resources to optimize learning (Soderstrom, Clark, Halamish, & Bjork, 2015; see also Bjork, 1999 for a review). Empirically, information about learning processes can be obtained through metacognitive judgments. Though these tasks have received significant attention from memory researchers (see Bjork, 2016; Metcalfe, 2000, for a historical overview of metamemory judgments), few studies have examined whether the act of providing metamemory judgments at study can affect subsequent performance and if so, determine the memory processes that are affected.

A common type of judgment used to assess online metamemory processes is the judgment of learning (JOL) task. In a standard JOL task, participants are presented with a cue-target study pair (e.g., paired associates) and are asked to respond with the likelihood that they would retrieve the correct target at test if provided with only the cue. While these judgments can be made using a variety of scales (e.g., Likert scales or binary “yes”-“no” responses; Hanczakowski, Zawadzka, Pasek, & Higham, 2013), JOLs are typically elicited using a continuous 0 to 100 scale that represents the percent likelihood that the cue-target pair would be successfully recalled at test (e.g., 100% = definitely would remember; 0% = definitely would not remember). The use of a 100-point scale allows for a comparison between predicted recall (via JOLs) and the proportion of target items later recalled at test.

Recently, several studies have examined whether providing JOLs at study is *reactive*. JOL reactivity refers to changes in memory due to providing JOLs at encoding. A simple way to assess whether JOLs produce a reactive effect on learning is to compare recall performance for participants who complete a JOL task at study to those who do not (e.g., Janes, Rivers, & Dunlosky, 2018, Soderstrom et al., 2015). Reactivity could produce a memory benefit (i.e., *positive reactivity*) or a memory cost (i.e., *negative reactivity*) relative to a no-JOL task. Thus, evaluating reactivity simply involves the inclusion of a no-JOL control group, a comparison that is generally absent in JOL studies as researchers have either been interested in condition-specific effects on JOLs themselves and less on overall memory performance or have assumed that the act of providing JOLs at study has no impact later memory. However, given that no-JOL control groups are often absent, this assumption cannot be confirmed.

The lack of no-JOL controls across studies is surprising given early evidence for the reactive effects of JOLs on memory as reported by Arbuckle and Cuddy (1969. In one experiment, metacognitive judgments were elicited using a 1-5 Likert scale, and importantly, participants provided metamemory judgements either during both study and test phases, or only at test. Judgments at study were framed as a JOL (i.e., predicted likelihood of recalling the target in the presence of a cue at test), while judgments made at retrieval were elicited as a confidence rating (i.e., confidence that the memory response was correct). This design allowed for a comparison between groups in which metacognitive judgments were provided at both study and test versus a group that only made judgements at test (i.e., a no-JOL control). A positive reactivity pattern was found in which correct recall was greater when judgments were provided at encoding. However, it is important to note that although Arbuckle and Cuddy reported that JOLs can boost recall, participants in both the JOL and no-JOL groups provided confidence ratings at test, making it unclear whether confidence ratings were a requisite for positive reactivity.

More recently, Soderstrom et al. (2015) had participants study a list of cue-target pairs which contained both related and unrelated pairs. After studying each pair, one group of participants were instructed to provide JOLs, while a no-JOL control group studied each pair in isolation. Participants were then tested on their recall of the target word when presented with the cue without additional metacognitive judgments made at retrieval (cf. Arbuckle & Cuddy, 1969). Overall, target recall was greater for participants who provided JOLs initially versus those who did not; however, this positive reactivity pattern was restricted to related pairs. For unrelated pairs, target recall did not differ between the JOL and no-JOL groups. A similar pattern was reported by Janes et al. (2018), who also showed that initial JOLs produced positive reactivity for targets from related but not unrelated pairs. Furthermore, Witherby and Tauber (2017) found evidence for positive reactivity on related pairs after a 48-hour retention interval, providing evidence for positive reactivity after a delay.

In contrast to the positive reactivity for JOLs associated with related pairs as reported by Soderstrom et al. (2015) and Janes et al. (2018), Mitchum, Kelly, and Fox (2016) reported a divergent pattern of reactivity. In their study, participants who provided JOLs at study showed no difference in later recall relative to a no-JOL group on related pairs and produced a negative reactivity pattern relative to the no-JOL group for unrelated pairs. Mitchum et al. interpreted this discrepancy as arising from methodological differences between their study and Soderstrom et al., such as differences in experimenter-paced study and the inclusion of a generation task in their second experiment. However, in a subsequent experiment that used experimenter-paced study, Mitchum et al. again found no evidence for positive reactivity on related pairs and negative reactivity on unrelated pairs. Taken together, these studies demonstrate that providing JOLs at study can induce reactivity on target learning, but the direction of the reactivity is mixed, with positive or no reactivity reported when pairs are related and negative or no reactivity reported with unrelated pairs.

**Mechanisms of JOL Reactivity**

Three mechanisms have been proposed to account for JOL reactivity (see Mitchum et al., 2016). First, the *positive reactivity hypothesis* states that given monitoring is essential for determining the effectiveness of the learning process (e.g., Nelson & Narens, 1990), retention will benefit from any additional monitoring that occurs as a byproduct of providing JOLs at encoding. Because JOLs are provided for all pairs at study, a global memory improvement should occur across study materials relative to a non-JOL control. Next, the *dual-task* *hypothesis* suggests that generating JOLs at encoding will produce negative reactivity across study materials versus a no-JOL control, as providing JOLs is resource demanding and may interfere with the learning of word pairs (Hertzog, Dunlosky, Powell-Moman & Kidder, 2002). Finally, the *changed-goal hypothesis* proposes that JOL reactivity occurs due to online changes in participant study goals that arise during encoding. According to this hypothesis, participants set an initial goal of memory mastery and strategically allocate more encoding time and/or effort towards studying items perceived as challenging to remember relative to those perceived as easy. However, certain conditions may induce a change of study goal in which easier items are prioritized. For example, Metcalfe & Kornell (2003) presented participants with English-Spanish vocabulary pairs and found that when study time was limited, participants prioritized learning of pairs perceived as “easy” due to a shared root word (i.e., cognate pairs, *park* - *parque*) versus more difficult pairs that did not contain the same root word (i.e., non-cognate pairs, *dog – perro*).When providing JOLs (specifically those utilizing a 0-100 rating scale), it becomes clear to participants that not all items will be equally recalled. Thus, participants may use perceptions of item difficulty when providing JOLs to shift their study goals towards mastering easier items.

Within the context of JOL reactivity on word pairs, the changed-goal hypothesis assumes that study lists will provide participants with at least two distinct pair types and that participants will be able to discern them. This hypothesis predicts that providing JOLs will induce positive reactivity for pairs perceived as easy to remember, but negative reactivity for pairs perceived as difficult to remember. This is because when individuals detect differences in difficulty between pair types, they prioritize encoding of the easier to remember related pairs at a cost of encoding more difficult unrelated pairs. Thus, for related and unrelated pairs, the changed-goal hypothesis predicts a divergent memory pattern when comparing JOL to a non-JOL group due to participant perceptions of pair difficulty.

Although JOL reactivity patterns based on pair association have been mixed (e.g., Janes et al., 2018; Mitchum et al., 2016; Soderstrom et al., 2015), a meta-analysis conducted by Double, Birney, and Walker (2018) which included 17 published and non-published experiments comparing JOL to non-JOL groups provided no support for the positive reactivity and dual-task hypotheses while showing only partial support for the changed-goal hypothesis. Specifically, providing JOLs yielded a positivity effect for related target recall, but showed no reactivity on recall of unrelated targets relative to no-JOL controls. In terms of the changed-goal hypothesis, it therefore appears that individuals prioritize encoding of related pairs when making JOL ratings, but this priority is not accompanied by a concomitant cost to the encoding of unrelated pairs.

To address the link between pair relatedness and positive JOL reactivity, Soderstrom and colleagues (Myers, Rhodes, & Hausman, 2020; Soderstrom et al., 2015) introduced an account based on Koriat’s (1997) cue-utilization theory in which the act of making JOLs at encoding reinforces relatedness cues that are used when participants make JOLs. By further strengthening these cues, the JOL task functions akin to a generation task (e.g., Slamecka & Graf, 1978), boosting recall for pairs that receive JOLs at study. However, according to this account, generation should occur globally, regardless of the associative strength of the cue and target. Therefore, reactivity should occur for both related and unrelated pairs, rather than being limited to only related pairs as is generally observed.

**Associative Direction and JOL Accuracy**

The associative direction between related word pairs has been shown to directly influence both how well individuals recall items at test and the accuracy of JOLs made at study. Koriat and Bjork (2005; see too Koriat & Bjork, 2006) demonstrated that across three experiments, JOLs for pairs associated in the forward direction (e.g., credit-card) were accurate at predicting later recall of the target item. When forward association strength between pairs was weak (e.g., article-newspaper), JOLs were less predictive of later recall relative to when the forward association between pairs was strong (e.g., lost-found). For weak forward pairs, JOLs were similar to those given to strong associates, but recall was reduced as weakly related cues were less effective in aiding retrieval of the target. Thus, the calibration between JOLs and recall was moderated by the strength of the forward cue-target association.

In addition to forward associates, Koriat and Bjork (2005; Experiment 2) also evaluated the correspondence between JOLs and target recall for pairs associated in the backward direction (e.g., card-credit). Like weak associates, backward associates received high JOL ratings, but recall for the target word was considerably lower relative to forward pairs. Dubbed the *illusion of competence,* this overestimationpattern has been extended to other pair types. Castel et al. (2007) showed that the illusion of competence extended to identical pairs in which the cue is perfectly predictive of the target (e.g., lost-lost). More recently, Maxwell and Huff (in press) showed that the illusion of competence holds for backward associates after controlling for lexical and semantic properties of the cue and target (e.g., word length, concreteness, etc.) and extends to symmetrical associates (e.g., off-on). Thus, the direction of association more so than the associative strength, contributes to the illusion of competence.

The illusion of competence serves as an example of how the directional correspondence between related pairs can affect the predictive capacity of JOLs on later recall. Regarding JOL reactivity, most studies use forward associate pairs in which the cue is highly predictive of the target. In a notable exception, Mitchum et al. (2016, Experiment 1), compared target recall using forward associates, backward associates, and unrelated pairs that were presented within the same study list. Study latencies were also measured. As reported above, no reactivity was found for either backward or related pairs. Yet, despite this null pattern, the authors concluded that the changed-goal hypothesis was partially supported as JOL participants spent less time studying unrelated pairs relative to participants who did not make JOL ratings. This pattern suggests that participants were prioritizing memorization of related pairs by allocating additional study time.

Although Mitchum et al. (2016) showed reactivity results inconsistent with other JOL reactivity studies (e.g., Janes et al., 2018; Soderstrom et al., 2015), it is also worth pointing out another inconsistency in their data—no illusion of competence pattern emerged for backward pairs (cf. Castel et al., 2007; Koriat & Bjork, 2005; Maxwell & Huff, in press). Though Mitchum et al. reported reduced recall rates for backward than forward pairs across JOL and non-JOL groups, these differences were much smaller than those typically reported. This discrepancy may have resulted from how association was measured across these studies. Koriat and Bjork (2005) for instance used Hebrew word pairs derived from a set of Hebrew free association norms, while Mitchum et al. used English word pairs derived from the University of South Florida Free Association Norms (USF norms; Nelson, McEvoy, & Schreiber, 2004) as well as a relatedness score calculated with Latent Semantic Analysis (LSA; Landauer & Dumais, 1997). Maxwell and Huff (in press) similarly utilized the USF norms as in Mitchum et al. and used pairs that were identical in associative strength (0.37 in both studies); however, a robust illusion of competence pattern was found.

A second possibility for this discrepancy is that while association between pair types was assessed and manipulated, neither Koriat and Bjork (2005) nor Mitchum et al. (2016) controlled for lexical and semantic item characteristics of cues and targets that may have covaried across pair types. Characteristics such as word length, frequency, and concreteness have each been shown to affect later recall (Balota & Neely, 1980; Criss, Aue, & Smith, 2011; Madan, Glaholt, & Caplan, 2010) and could be confounded with associative direction in these studies. Thus, given discrepancies in recall that occur as a result of pair direction (i.e., the illusion of competence), it remains unclear whether pair direction could moderate JOL reactivity (i.e., greater reactivity for forward vs. backward pairs).

The goal of the present study was therefore to examine pair associations as a means of testing potential mechanisms that contribute to JOL reactivity. First, Experiment 1 was designed to provide a replication of JOL reactivity patterns reported by Janes et al. (2018) and Soderstrom et al. (2015) to further test the reliability of positive reactivity for related pairs and no reactivity for unrelated pairs while controlling for lexical and semantic characteristics of cues and targets. Additionally, we compared reactivity effects on four different pair types including three types of related pairs (forward, backward, and symmetrical) and unrelated pairs. Next, given that previous research has shown JOL reactivity to be contingent upon pair association, Experiment 2 tested a novel strategic relational encoding account of reactivity. Briefly, the strategic relational encoding account posits that when participants are exposed to related and unrelated pairs, they strategically emphasize processing of relational characteristics of related (but not unrelated) pairs, leading to their greater recall. To test this account, we compared target recall in JOL and no-JOL groups relative a relational encoding group in which participants were explicitly instructed to relate all study pairs together. In this latter group, relational encoding is a non-strategic task as participants are instructed to use relational encoding on all pair types rather than choosing to use relational encoding on different subsets. We further compared these groups relative to a shallow levels-of-processing task to provide an additional control group.

Experiments 3 and 4 provided stronger tests of the strategic relational encoding account by comparing recall in the JOL and no-JOL groups to a group that completed either the judgment of associative memory task (JAM; Experiment 3) or a frequency-rating task (Experiment 4). The JAM task was utilized because it is a relational-encoding task that incorporates a similar rating process as JOLs, whereas the frequency task was designed to mimic this rating process without emphasizing the semantic relations between the cue and target. In doing so, both experiments allowed participants to provide ratings while removing the predictive component associated with JOLs. Thus, both Experiments 3 and 4 also evaluated whether JOL reactivity effects are due to the memorial forecasting that occurs when providing a JOL or due to rating cue-target pairs within the same context, which encouraged relational encoding.

To preview, across all experiments, we found reliable positive JOL reactivity for all three related pair types, consistent with the general pattern in the literature (cf. Double et al., 2018). Furthermore, we found that the benefit to related pairs when participants make JOLs is equivalent to the benefit related pairs receive when studied using an explicit relational encoding task, suggesting that participants deploy relational encoding for related, but not unrelated pairs, when providing JOLs. We then show that both JAMs and frequency judgments elicit identical patterns of reactivity as JOLs by boosting correct recall of only related pairs, suggesting that participants strategically allocate relational processing to related pairs, even when memory forecasting is not used. Collectively, our experiments reveal that reactivity patterns are not unique to JOLs and reflect strategic use of relational encoding directed towards related pairs.

**Experiment 1: JOL Reactivity on Related and Unrelated Pairs**

The purpose of Experiment 1 was to replicate and extend previous JOL reactivity patterns by comparing target recall following study of related and unrelated pairs. The changed-goal hypothesis predicts that JOL reactivity should produce a benefit to related pairs and a cost to unrelated pairs as participants shift their study goals to prioritize the easier related pairs over unrelated pairs. Because prior studies only find partial support for the changed-goal hypothesis with positive reactivity for related pairs and no effect on unrelated pairs (e.g., Double et al., 2018), we expected that our experiment would yield this same pattern.

An additional goal of our experiment was to evaluate positive reactivity on different types of related pairs. We therefore compared forward and backward pairs, but also included symmetrical pairs—a related pair type that has not yet been tested in reactivity experiments. We expected that positive reactivity would be found across all three related pairs despite differences in recall rates (Maxwell & Huff, in press). Importantly, we also controlled for lexical and semantic item effects that were not equated for across pair types in previous studies (e.g., Janes et al., 2018; Soderstrom et al., 2015). All related and unrelated pairs were matched on word frequency, concreteness, and length and related pairs were further matched on associative strength. Thus, Experiment 1 provides a more precise test of JOL reactivity patterns while controlling for important lexical and semantic item effects.

**Method**

**Participants**

Seventy-eight participants were recruited online through Prolific (www.prolific.co) and were compensated at a rate of $8.00/hour. Participants were randomly assigned to either the JOL or no-JOL group (39 per group). A sensitivity analysis conducted with G\*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that this sample size provided adequate power (0.80) to detect medium-sized main effects/interactions (Cohen’s *d* = 0.50) or larger. All participants were native English speakers with normal or corrected-to-normal vision.

**Materials**

Stimuli pairs were taken from Maxwell and Huff (in press). These pairs consisted of 180-word pairs generated from the University of South Florida Free Association Norms (Nelson et al., 2004). Pairs were split into four types consisting of 40 forward pairs (e.g., credit-card), 40 backward pairs (e.g., card-credit), 40 symmetrical pairs in which forward and backward strength were equivalent (e.g., ball-bounce), and 40 unrelated pairs (e.g., artery-bronze). Additionally, 20 non-tested buffer pairs were generated to control for primacy and recency effects. Item pairs were distributed across two study lists of 90 items which were used in two separate study/test blocks. Thus, each list contained 20 items of each of the four pair types and 10 buffer items. Pairs are available at https://osf.io/8yvn3/.

Study lists were created such that the 80 tested pairs were always proceeded and followed by five buffer pairs to reduce primacy and recency effects. Additionally, lists were constructed such that pair types were equated on frequency (SUBTLEX; Brysbaert & New, 2009), word length, and concreteness (from the English Lexicon Project; Balota et al., 2007) and related pair types were further equated associative strength (e.g., FAS and BAS values derived from the Nelson et al. (2004) free association norms; see Tables A1-A2 in Appendix for associative strength and lexical properties for each pair type). Finally, counterbalanced versions of each study list were created that flipped the order of words with each of the four pair types (i.e., king-queen becomes queen-king). While the order was switched across all pair types, this was especially important for forward and backward pair types given forward pairs were transformed to backward pairs, making these pair types perfect controls. The cued-recall test was generated from all 80 cue items (excluding buffers) by replacing the target item with a question mark (i.e., credit - ?). Test items were presented in a newly randomized order for each participant.

**Procedure**

Data collection was conducted online using *Collector*, an open-source program for presenting web-based psychological experiments (Garcia & Kornell, 2015). In both the JOL and No-JOL groups, participants were instructed that they would view a series of cue-target word pairs and that their memory for the target item would be tested. Participants in the JOL group received further instruction to rate the likelihood that they would be able to remember the target word if shown only the cue at test. Judgments were elicited using a scale of 0-100, in which 0 indicated that they would be completely unable to recall the item at test, while a rating of 100 represented full certainty in their ability to correctly recall the target. After receiving instructions, participants began the first study list. Study was self-paced, with both groups pressing the Enter key to advance to the next pair. Additionally, participants in the JOL group were asked to type a JOL rating before advancing to the next study pair. JOL ratings were provided concurrently with study such that ratings were typed while the pair was displayed.

Following presentation of the first study list, participants completed a two-minute filler task in which they were asked to list the 50 U.S. states in alphabetical order. This was immediately followed by a cued-recall test that presented participants with the cue word from each of the previously studied items. Participants were asked to type the correct target item. If participants could not retrieve the correct item, the Enter key could be pressed to advance to the next pair. Following the first cued-recall test, participants began the second block, which followed the format of the first block. Participants were fully debriefed following the completion of the second cued-recall test. Each experimental session lasted approximately 30 minutes.

**Results**

A *p* < .05 significance level was used for all analyses. Partial eta-squared (*ηp*2)and Cohen’s *d* effect sizes are reported for all significant analyses of variance (ANOVAs) and *t*-tests. For all *t*-tests, we report standard test statistics, but note that all comparisons hold when using a Bonferroni correction. Additionally, for all non-significant main effects and post-hoc comparisons, we report a Bayesian estimate of the strength of the evidence supporting the null hypothesis (Masson, 2011; Wagenmakers, 2007). This analysis compares two models, one in which a significant effect is assumed, and one that assumes a null effect. From this analysis, a probability estimate is generated, a *p*-value termed *p*BIC (Bayesian Information Criterion), which estimates the probability that the null hypothesis is retained. This estimate is sensitive to the sample size, providing increased confidence in null effects reported. For completeness, encoding durations for experimental groups across pair types are reported in our Supplemental Materials with data available on our OSF page (https://osf.io/8yvn3/).

Figure 1 (top panel) plots mean JOL ratings and cued-recall rates for each pair type for participants in the JOL study group, while the bottom panel compares recall rates for participants who made JOLs at study versus those who silently read pairs at study. A liberal scoring criterion was adopted for recall such that misspellings and grammatical errors (i.e., changes in tense) were counted as correct. All comparisons between of JOL ratings and correct recall proportions for each pair type are displayed in Appendix Table A3, and all comparisons between correct recall proportions for JOL and no-JOL groups are reported in Table A4. All analyses have been collapsed across block order1. In our analyses, we first test for an illusion of competence pattern in the JOL group given this pattern has not been reported consistently in JOL reactivity studies (cf. Mitchum et al., 2016). We then test for reactivity patterns across pair types by comparing the JOL and no-JOL groups.

First, we conducted a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 2 (Measure: JOL vs. Recall) repeated measures ANOVA to assess whether the illusion of competence first reported by Koriat and Bjork (2005) replicated for participants in the JOL group. A main effect of Pair Type was found, *F*(3, 114) = 421.81, *MSE* = 99.94, *ηp*2 = .92, in which JOLs/recall rates were highest for forward pairs (65.10), followed by symmetrical pairs (61.32), backward pairs (43.40), and unrelated pairs (14.14). Post-hoc *t*-tests showed that JOLs/recall rates significantly differed across all comparisons, *t*s ≥ 4.42, *d*s ≥ 0.32. Next, a significant effect of measure was observed, *F*(1, 38) = 10.02, *MSE* = 521.91, *ηp*2 = .21, in which JOL ratings (50.07) exceeded later recall rates (41.90). Importantly, a significant interaction between Pair Type and Measure, *F*(3, 114) = 68.55, *MSE* = 49.40, *ηp*2 = .64, confirmed the presence of an illusion of competence pattern. Follow-up *t-*tests indicated a robust illusion of competence for backward pairs whereby JOLs greatly exceeded later recall accuracy (55.18 vs. 31.67), *t*(38) = 7.59, *SEM* = 3.21, *d* = 1.56. Additionally, the illusion of competence extended to unrelated pairs (19.43 vs. 8.85), *t*(38) = 3.97, *SEM* = 2.75, *d* = 0.87, and symmetrical pairs (64.83 vs. 57.78), *t*(38) = 2.32, *SEM* = 3.14, *d* = 0.47, though the difference between judgments and recall smaller than backward pairs. Finally, for forward pairs, this pattern reversed—JOL ratings were significantly lower than cued-recall rates (60.87 vs. 69.34), *t*(38) = 2.93, *SEM* = 2.98, *d* = 0.57, indicating that participants underestimated their performance for this pair type and performed better than predicted at test.

Next, we tested JOL reactivity patterns by comparing the pair types across study groups using a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 2 (Study Group: JOL vs. No-JOL) mixed ANOVA. A main effect of Pair Type was found, *F*(3, 228) = 512.24, *MSE* = 75.53, *ηp*2 = .87, indicating that across study groups, correct recall was greatest for forward pairs (58.69), followed by symmetrical pairs (46.89), backward pairs (23.88), and unrelated pairs (9.26). Post-hoc *t*-tests indicated that all comparisons differed significantly, *t*s ≥ 7.79, *d*s ≥ 1.27. An effect of Study Group was also found, *F*(1, 76) = 26.01, *MSE* = 623.74, *ηp*2 = .26, in which correct recall in the JOL group (41.89) exceeded the no-JOL group (27.47), indicating an overall JOL reactivity pattern. Importantly however, a significant interaction was found, *F*(3, 228) = 28.71, *MSE* = 75.53, *ηp*2 = .27, and post-hoc tests indicated that positive reactivity was confined to related pairs. Correct recall in the JOL group exceeded that of the no-JOL group for forward pairs (69.29 vs. 48.07), symmetrical pairs (57.78 vs. 36.03), and backward pairs (31.67 vs. 16.09), *t*s ≥ 4.90, *d*s ≥ 1.11. However, for unrelated pairs (8.85 vs. 9.68), no reactivity was found, *t* < 1, *p*BIC = .88. Thus, JOLs only appear to benefit cued-recall performance when item pairs are related.

**Discussion**

The results from Experiment 1 are quite clear. Providing JOLs at study greatly increased correct recall of targets for forward, backward, and symmetrical related pairs relative to a no-JOL control. For unrelated pairs, however, providing JOLs had no effect on later recall compared to the no-JOL group. The finding that JOL reactivity effects on related pairs generalize to different types of directional associates that are matched on several lexical and semantic characteristics indicates that JOL reactivity effects occur for related pairs more broadly and are not specific to one associative direction. The JOL reactivity pattern is therefore consistent with the patterns reported in other reactivity studies (Double et al., 2018; Janes et al., 2018; Soderstrom et al., 2015).

Also consistent with prior studies were the illusion of competence patterns found for backward, symmetrical, and unrelated pairs in the JOL group. For these pair types, JOLs exceeded later recall rates, and this pattern was particularly robust for backward pairs given the cue word at test was a poor predictor of the target. The illusion of competence indicates that JOLs were poorly calibrated to later recall. In contrast, JOLs for forward pairs, in which the cue was a strong predictor of the target at test, were better calibrated to later recall and even underpredicted later recall. These patterns are generally consistent with previous studies (e.g., Koriat & Bjork, 2005; Castel et al., 2007).

Regarding JOL reactivity, the finding that positive reactivity effects are found for related pairs, but negative reactivity is not found for unrelated pairs is inconsistent with a changed-goal account. Related pairs, regardless of their associative direction, are prioritized at encoding, leading to their elevated recall. Given this pattern, it is likely that participants are strategically processing related over unrelated pairs leading to an unrelated cost. Given the associative relations between the cue and target for related pairs, we suggest that participants are engaging in relational encoding in which participants emphasize shared features or characteristics of a study set (Einstein & Hunt, 1980; Hunt & Einstein, 1981). Because JOLs only produce a recall benefit for related pairs, we suggest that providing JOLs results in a strategic use of relational encoding which is applied to related but not unrelated pairs.

The use of relational encoding is likely contextually driven by the specific pair type that is studied. Previous research has found that the study materials themselves can affect whether participants engage in relational encoding. For instance, Hunt and Seta (1984) suggested that increasing the number of categorically related items in a study list will increase the use of relational encoding. Similarly, Huff and Bodner (2014) reported that using an explicit relational encoding task on strongly related study materials was less effective at improving recall relative to using a relational encoding task on weakly related study materials. This pattern was interpreted as a redundancy in processing in which processing from an explicit relational study task overlaps with relational encoding that is being fostered from a strongly related list. This pattern is important because it indicates that both the study task and the study materials can qualitatively affect encoding processes. In terms of JOL reactivity, we argue that the cue-target relations being used marshal relational encoding, but only when participants perceive pairs as related (i.e., strategic relational encoding). However, in contrast to the changed-goals hypothesis, detecting unrelated pairs does not lead to a reduction in encoding and a subsequent memory cost. Therefore, although providing JOLs is not an explicitly relational encoding task, participants may strategically engage in relational encoding when related pairs are detected, leading to their positive reactivity.

To account for JOL reactivity, researchers have also posited a cue-strengthening account (Soderstrom et al., 2015), in which providing JOLs allow for the generation of cues that can subsequently be used at retrieval. However, pair relatedness is not a requirement for the generation effect to occur, as this effect has been observed using single words (i.e., rather than paired associates; Mulligan, Smith, & Buchin, 2018) and has been shown to extend to unrelated item pairs (McCurdy, Viechtbauer, Sklenar, Frankenstein, & Leshickar, 2020). Thus, if JOLs operate in a manner similar to generation, positive reactivity should also be observed for unrelated pairs. Instead, we suggest that JOL reactivity is primarily driven by pair relatedness. The JOL task implicitly directs attention to pair relatedness; thus, participants selectively engage in relational encoding for related study pairs, matching reactivity patterns that are generally reported (e.g., Janes et al., 2018; Soderstrom et al., 2015).

**Experiment 2: JOLs versus Relational Encoding**

In Experiment 2, we tested whether positive reactivity found for related pairs following JOLs versus no-JOLs was due to the strategic use of relational encoding. We tested this possibility by comparing standard JOL and no-JOL groups to a relational encoding group which was given intentional encoding instructions to relate all pairs together at study. We reasoned that if the JOL group employs relational encoding strategically on related pairs leading to reactivity, then this pattern of reactivity should be equivalent to related pair recall rates for participants that are explicitly using relational encoding. Furthermore, because recall is typically greater following relational encoding relative to standard read-only intentional instructions (Huff & Bodner, 2014; 2019), we expected that recall would be increased following relational encoding instructions relative to the no-JOL group.

We note that the relational encoding instructions differ from the strategic relational encoding processes which posits that all relational encoding accompanying JOLs is only applied to related but not unrelated pairs. Having participants in the relational group apply this task to all pairs (rather than selectively to related pairs as predicted by strategic relational encoding) was used because explicit relational encoding instructions have been shown to spill over into other encoding tasks when encoding is manipulated within-subjects (Huff, Bodner, & Gretz, in press). Given these carryover issues, it was reasonable to have participants utilize relational encoding for all pair types rather than a subset which could potentially bleed over to unrelated pairs. In addition to the relational encoding group, we also included a shallow levels-of-processing group (i.e., vowel-counting task) to serve as an additional control. The inclusion of this group allowed us to ensure that any recall benefits found in the relational encoding group were due to relational encoding and not due to the use of an explicit encoding task.

Consistent with Experiment 1, we expected a positive reactivity pattern for the JOL versus no-JOL group. Additionally, we expected that relational encoding would also produce a recall benefit that would mimic the positive reactivity pattern in the JOL group on related pairs, consistent with the strategic relational encoding account. However, we also expected that the recall of unrelated pairs would be greater in the relational-encoding group relative to the JOL group. This is because the explicit relational task forces participants to utilize relational encoding regardless of pair type, which will likely benefit memory for unrelated pairs. Finally, we expected that the shallow group would produce lower levels of recall, possibly even lower than the no-JOL group since shallow processing is ineffective for promoting long-term memory.

**Methods**

**Participants and Stimuli**

A total of 167 participants were recruited for Experiment 2. Participants were recruited from two sources. First, we recruited 84 undergraduate psychology students recruited from The University of Southern Mississippi who completed the study online for partial course credit. The remaining 83 participants were recruited online via Prolific and were compensated at a rate of $8.00/hour2. Participants were randomly assigned to the JOL group (*n* = 39), the no-JOL group (*n* = 40), the relational encoding group (*n* = 45), and the shallow group (*n* = 43). All participants were native English speakers with normal or corrected-to-normal vision.

**Materials and Procedure**

The same materials and general procedure from Experiment 1 were again used in Experiment 2 with the exception of two additional encoding tasks. Participants in the relational-encoding group were instructed to think about how the two concepts were related to one another. The pair *cat-turtle­* was provided as an example, and participants in this group were instructed to consider overlapping features shared between the two concepts while studying the pairs (i.e., both are animals, have four legs, and can be kept as pets, etc.). In the vowel-counting group, participants were instructed to report the number of vowels in both the cue and target items. Both the relational encoding and shallow groups did not provide JOL ratings at study as in the no-JOL group and were instructed to apply their encoding strategy to all study pairs. After viewing each pair and studying it using their respective encoding strategy, participants pressed the enter key to move to the next pair. Participants in the JOL and no-JOL groups followed the same procedure used in Experiment 1 including completion of the 2-minute filler task and cued-recall test.

**Results**

The top panel of Figure 2 displays mean JOL ratings and cued-recall rates for each pair type for participants in the JOL group, while the bottom panel displays mean cued-recall rates for each of the four encoding strategies as function of pair type. To test for the illusion of competence, we first conducted a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 2 (Measure: JOL vs. Recall) repeated measures ANOVA, assessing only participants who completed JOL encoding task. Consistent with Experiment 1, a main effect of Pair Type was found, *F*(3, 114) = 363.39, *MSE* = 112.72, *ηp*2 = .91, in which JOLs/recall rates were highest for forward pairs (65.68), followed by symmetrical pairs (63.15), backward pairs (44.43), and unrelated pairs (16.06). All comparisons differed significantly, *t*s ≥ 2.48, *d*s ≥ 0.22. A significant effect of Measure was also found, *F*(1, 38) = 50.54, *MSE* = 464.04, *ηp*2 = .57, such that JOL ratings (56.03) exceeded cued-recall rates (38.69). Finally, a significant interaction between Pair Type and Measure was found, indicating the presence of an illusion of competence, *F*(3, 114) = 56.41, *MSE* = 61.67, *ηp*2 = .60. Post-hoc tests indicated that an illusion of competence occurred for backward pairs such that JOLs greatly exceeded later recall rates (62.18 vs. 26.67), *t*(38) = 12.02, *SEM* = 3.05, *d* = 2.63. This pattern also occurred on unrelated pairs (22.30 vs. 9.87), *t*(38) = 4.07, *SEM* = 3.16, *d* = 0.96, and symmetrical pairs, (71.89 vs. 54.17), *t*(38) = 6.49, *SEM* = 2.79, *d* = 1.18. The illusion of competence, however, was not found on forward pairs, (67.63 vs. 63.78), but unlike Experiment 1, JOLs were equivalent to recall rates *t*(38) = 1.38, *SEM* = 2.91, *p* = .17, *p*BIC = .71.

We then examined reactivity patterns across encoding tasks, using a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 4 (Study Group: JOL vs. No-JOL vs. Relational Encoding vs. Shallow Encoding) mixed ANOVA. An effect of Pair Type, *F*(3, 489) = 691.11, *MSE* = 78.13, *ηp*2 = .81, indicated that correct recall was highest for forward pairs (52.17), followed by symmetrical pairs (42.95), backward pairs (22.28), and lowest for unrelated pairs (13.73), which all differed statistically from each other, *t*s ≥ 10.72, *d*s ≥ 0.44. A main effect of Study Group was also found, *F*(1, 163) = 10.56, *MSE* = 1166.90, *ηp*2 = .16, in which correct recall was highest in the relational encoding group (41.06), followed by the JOL group (38.61), the no-JOL group (28.11), and shallow group (23.18). Post-hoc *t*-tests indicated that cued-recall rates in the JOL and relational encoding groups differed significantly from the no-JOL and shallow groups tasks (*t*s ≥ 4.14, *d*s ≥ 0.93), but did not differ between each other, *t* < 1, *p*BIC = .88. Additionally, there was no difference between the no-JOL and shallow groups, *t*(69) = 1.48, *SEM* = 3.39, *p* = .14, *p*BIC = .76.

The effects of Pair Type and Study Group were qualified by a significant interaction, *F*(9, 489) = 13.29, *MSE* = 78.13, *ηp*2 = .03. Beginning with forward pairs, correct recall was highest in the JOL group (63.78), followed by the relational group (58.17), the no-JOL control group (48.06), and the shallow group (39.19). All comparisons differed significantly (*t*s ≥ 2.13, *d*s ≥ 0.47), with the exception of the JOL and relational group, *t*(75) = 1.37, *SEM* = 4.18, *p* = .18, *p*BIC = .79. This same pattern was also found with symmetrical pairs: Correct recall was highest in the JOL group (54.17), followed by the relational group (50.06), the no-JOL group (38.13) and shallow group (29.83). All comparisons differed significantly, *t*s ≥ 2.06, *d*s ≥ 0.45, again with the exception of the JOL and relational groups, *t* < 1, *p*BIC = .79. For backward pairs, correct recall was highest in the relational group (30.89), followed by the JOL group (26.60), the no-JOL group (17.13), and the shallow group (14.13). Follow up *t*-tests showed that recall rates in the JOL and relational groups differed from both the no-JOL and shallow groups (*t*s ≥ 3.24, *d*s ≥ 0.77). Recall did not differ between the JOL and relational group (26.60 vs. 30.89), or between no-JOL and shallow groups (17.13 vs. 14.13), *t*s < 1, *p*s ≥ .33, *p*BICs ≥ .85. Finally, for unrelated item pairs, recall rates were highest for the relational group (25.11) relative to the JOL task (9.87), the no-JOL group (9.13), and the shallow group (9.59, *t*s ≥ 3.73, *d*s ≥ 0.74). All other comparisons were non-significant, (*t*s < 1, *p*s ≥ .73, *p*BICs ≥ .90).

**Discussion**

Experiment 2 produced three notable outcomes. First, the illusion of competence pattern observed in Experiment 1 was again in evidence. Second, the JOL reactivity pattern found in Experiment 1 was found such that providing JOLs at study facilitated recall for related targets, but not for unrelated targets. Third, and most importantly, the JOL reactivity pattern found in related pairs mimicked related pairs in the relational encoding group that was instructed to explicitly associate pairs together at encoding. This similarity suggests that JOL participants are engaging in deep relational encoding of related pairs despite not receiving instructions to do so. Positive reactivity was similarly found when comparing the JOL and relational groups to the shallow-encoding group, indicating that reactivity effects hold relative to a shallow task. Recall did differ between the JOL and relational group for unrelated pairs. This pattern is likely due to relational participants employing their encoding task across all pair types as was instructed, rather than selectively limiting it to only related pairs as is likely occurring in the JOL group.

While similarities between relational encoding and the JOL group for related pair recall are consistent with a strategic use of relational encoding, a stronger test of this account would be to contrast the JOL task with a similar relational-type task that can be strategically applied at study. The relational encoding task given to participants in Experiment 2 was not strategic as participants were instructed to use relational encoding for all pair types and not selectively to a subset of pairs. In Experiment 3, we evaluate the strategic use of relational encoding by comparing JOLs to a JAM task (Maki, 2007), which similarly requires participants to process the cue and the target items together to provide an estimate of association at study. If participants display similar reactivity patterns when employing the JAM task compared to the standard JOL task, this suggests that participants are strategically deploying relational encoding to facilitate encoding of related over unrelated pairs.

**Experiment 3: JOLs versus Judgments of Associative Memory**

The goal of Experiment 3 was to provide a further test of the strategic relational encoding account by comparing JOL reactivity effects to a JAM task. In the JAM paradigm, participants are presented with a cue-target pair and are asked to estimate the percent likelihood that an individual would respond to cue with the presented target (Garskof, & Forrester, 1966; Nelson, Dyrdal, & Goodmon, 2005; see Maki, 2007 for a review). These estimates are typically framed as predicting the number of individuals out of 100 who would respond to the cue item with the presented target. In doing so, the JAM task is heavily dependent upon relational cues, as it gauges perceived association. Thus, like JOLs, JAMs should encourage relational encoding, especially when the cue and target are strongly related, and this encoding can be used strategically as participants are not given explicit relational encoding instructions.

By encouraging participants to process both the cue and target together, this task was designed to mimic the processing used by the JOL task. We elected to use JAMs due to similarity to the JOL task, as both require participants to process related aspects of the study pairs (either conceptually or their use together) and assign a judgment value. Further, ratings on both tasks are provided using the same scale, allowing for easy comparison. If participants are using relational encoding strategically on related word pairs, they would be able to use this encoding on both the JOL and JAM tasks. Of course, a key difference between the two tasks is that JOLs require participants to provide a recall forecast at encoding, whereas JAMs do not. Thus, an interesting question regarding JOL reactivity is whether memory predictions are necessary to produce a memory improvement. According to the strategic relational encoding account, only the use of relational encoding given to pairs at study will benefit memory, not necessarily whether a memory prediction is made. Thus, we expected memory forecasting via JOLs would not be necessary to produce reactivity effects.

**Methods**

**Participants**

70 participants were recruited from The University of Southern Mississippi’s undergraduate research pool and completed the study online for partial course credit. Additionally, 28 participants were recruited from Prolific and completed the study at a rate of $8.00/hour, leading to a total of 98 participants who completed Experiment 33. Participants were randomly assigned to either the JOL group (*n* = 33), the no-JOL group (*n* = 32), or the JAM group (*n* = 33). All participants were native English speakers who reported normal or corrected-to-normal vision.

**Materials and Procedure**

Experiment 3 used the same materials and followed the proceduredescribed in Experiment 1 with the following exception. In addition to the standard JOL and no-JOL groups, participants were also randomly assigned to a JAM task group in which they were asked to rate the likelihood in which the target word would be given as a response to the cue. Like JOLs, JAM ratings were elicited using a continuous 0-100 scale. JAM instructions were modeled after the associative judgment task used by Maxwell & Buchanan (2020; exact instructions are available at https://osf.io/6xgkt/). Specifically, JAMs were framed as the number of individuals out of 100 who would respond with the target word if shown only the cue (i.e., as is typical in a free-association task). As with the JOL task, JAMs were elicited concurrently with study, and study was self-paced across all groups. Thus, only the focal point of the two judgments differed.

**Results**

Figure 3 (top panel) plots mean JOL ratings and cued-recall rates for each pair type for participants completing the JOL task. The bottom panel displays mean recall as function of encoding group and pair type. Using a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 2 (Measure: JOL vs. Recall) repeated measures ANOVA, we tested for the illusion of competence in the JOL group. Consistent with our predictions, this analysis yielded a significant effect of Pair Type, *F*(3, 96) = 269.87, *MSE* = 127.66, *ηp*2 = .89 that closely followed the patterns reported across the previous experiments. Specifically, mean JOLs/recall rates were highest for forward pairs (69.02), followed by symmetrical pairs (65.36), backward pairs (47.76), and were lowest for unrelated items (18.61). Comparisons differed statistically across each pair type, *t*s ≥ 3.04, *d*s ≥ 0.29. Next, the effect of measure was also significant, *F*(1, 32) = 10.32, *MSE* = 693.79, *ηp*2 = .24, in which JOL ratings were greater than cued-recall (55.16 vs. 45.36). Finally, a significant interaction between Pair Type and Measure confirmed that the illusion of competence pattern, *F*(3, 96) = 38.71, *MSE* = 64.82, *ηp*2 = .55. Starting with backward pairs, post-hoc analyses revealed that JOLs greatly exceeded subsequent later recall (60.15 vs. 35.61), *t*(32) = 6.92, *SEM* = 3.78, *d* = 1.54, a pattern that was echoed in unrelated pairs, (23.94 vs. 13.41), *t*(32) = 2.77, *SEM* = 3.71, *d* = 0.59, and symmetrical pairs, (70.14 vs. 60.68), *t*(32) = 2.89, *SEM* = 4.15, *d* = 0.61. Finally, for forward pairs, JOLs and recall did not significantly differ (66.25 vs. 71.74), *t*(32) = 1.44, *SEM* = 3.58, *p* = .16, *pBIC* = .67.

To test for reactivity effects, we next conducted a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 3 (Study Group: JOL vs. JAM vs. No-JOL) mixed ANOVA on correct recall. An effect of Pair Type was found, *F*(3, 285) = 616.18, *MSE* = 81.46, *ηp*2 = .60, in which correct recall was highest for forward pairs (64.92), followed by symmetrical pairs (56.22), backward pairs (33.16), and lowest for unrelated pairs (14.82). All comparisons differed significantly, *t*s ≥ 8.08, *d*s ≥ 0.45. Next, an effect Study Group was detected, *F*(2, 95) = 3.90, *MSE* = 827.92, *ηp*2 = .06, in which correct recall was highest when participants made JOLs (45.36) and JAMs (44.85) at encoding relative to participants in the no-JOL control group (36.46). All comparisons differed statistically, *t*s ≥ 2.28, *d*s ≥ 0.57, with the exception of the comparison between the JOL and JAM groups, *t* < 1, *SEM* = 3.57, *p* = .88, *pBIC* = .88.

Importantly, a significant interaction between Pair Type and Study Group emerged, *F*(6, 285) = 9.82, *MSE* = 81.46, *ηp*2 = .04. Follow-up *t*-tests revealed that for forward pairs, correct recall in both the JOL (71.74) and JAM (67.58) groups exceeded that of the no-JOL group (55.16). Comparisons across all statistically differed, *t*s ≥ 2.93, *d*s ≥ 0.65, with the exception of the comparison between the JOL and JAM groups, which were equivalent, *t* < 1, *SEM* = 4.47, *p* *=* .35, *p*bic = .84. A similar pattern was observed for symmetrical pairs. Correct recall was greater for the JOL (60.68) and JAM (61.29) groups versus the no-JOL group (46.41). Again, all comparisons statistically differed *t*s ≥ 3.22, *d*s ≥ 0.80, except for the comparison between the JOL and JAM groups, *t* < 1, *SEM* = 4.54, *p* *=* .89, *p*bic = .87. For backward pairs correct recall in the JOL (35.61) and JAM (36.36) groups was again greater relative to the no-JOL group (27.34). Correct recall in the JAM and the No-JOL groups differed significantly, *t*(63) = 2.11, *SEM* = 4.35, *d* = 0.52, while the comparison between the JOL and the No-JOL groups was marginal, *t*(63) = 1.93, *SEM* = 4.37, *p* *=* .06, *p*bic = .56, *d* = 0.48. Recall did not differ between the JOL and JAM groups, *t*(64) < 1, *SEM* = 4.21, *p* *=* .86, *p*bic = .88. Finally, for unrelated pairs, recall rates were equivalent across the JOL (13.41), JAM (14.68), and no-JOL (16.95) groups, *t*s ≤ 1.23, *p*s ≥ .22, *p*bics ≥ .79. Taken together both JOL and JAM tasks resulted in equivalent reactivity on correct recall for related pairs and no reactivity on unrelated pairs.

**Discussion**

Experiment 3 provided an additional test of the strategic relational encoding account of reactivity by comparing the standard JOL task to a JAM. In both tasks, participants processed the cue-target relations prior to providing a judgment using the same 0-100 scale. Although the judgment type differs (recall forecasting vs. relatedness estimates), the reactivity patterns observed for related and unrelated pairs did not differ as a function of judgment type, suggesting that similar processing occurred between the two task types. Compared to the no-JOL control group, both the JOL and JAM groups showed increased correct recall of targets across forward, backward, and symmetrical pairs—a positive reactivity pattern, but produced no recall benefit on unrelated targets.

The similarity in recall rates between the JOL and JAM encoding groups yields several important findings regarding reactivity effects in recall of cue-target pairs. First, the similar reactivity patterns in the JOL and JAM tasks indicates that type of task employed at encoding may not be a critical factor as to whether or not a reactivity pattern emerges. Instead, the qualitative processing given to the cue and target by the task may be more impactful. Second, providing a memory prediction does not appear to be a requisite for positive reactivity on related pairs given the equivalence between the JOL and frequency groups. This finding is important in reference to other studies that have reported JOL reactivity patterns (e.g., Soderstrom et al., 2015; Mitchum et al., 2016) which have only compared JOL and no JOL groups and have not measured recall differences relative to additional, non-JOL encoding tasks. Finally, the finding that reactivity does not operate globally across all pair types suggests that reactivity processes are applied strategically, with an emphasis on related over unrelated pairs.

While the JAM task does not explicitly instruct participants to relate study pairs together at encoding, relatedness is still a focal point of this task as participants are required to estimate the association strength between two items. Because of this, JAMs may be more likely to induce relational encoding relative to JOLs. As such, a better test of the strategic relational encoding account would be to compare JOL reactivity to a judgment task that also does not call attention to the relational characteristics between items. To this end, Experiment 4 introduced a frequency judgment task in which participants were instructed to rate the likelihood that two words would be used together. Like JAMs, frequency judgments emphasize the correspondence between cues and targets, without explicitly instructing participant to relate all items together at encoding. However, the frequency judgment task places less emphasis on pair relatedness relative to JAMs, providing an encoding task that is more comparable to JOLs.

**Experiment 4: JOLs vs Frequency Judgments**

The primary goal of Experiment 4 was to provide a more complete test of the strategic relational encoding account by comparing JOL reactivity effects to a frequency judgment task. In the frequency judgment task, participants are asked to estimate the likelihood that the cue and target words would appear together contextually within the English language. We note that while the frequency task is still sensitive to pair relatedness, it does not explicitly direct participants to process pair relations. Overall, we expected that any observed reactivity would adhere to the strategic relational encoding account. Specifically, we anticipated that JOL group would again show positive reactivity for related pairs (forward, backward, and symmetrical), and would not differ on unrelated pairs relative to a no-JOL control, based on the previous experiments. Furthermore, consistent with the results of Experiment 3, we also expected that this pattern of reactivity would extend to the frequency judgment group, such that positive reactivity would be observed for related, but not unrelated pairs. Finally, we expected these patterns would be equivalent to the JOL group due to relational encoding of related pairs fostered by both tasks.

**Methods**

**Participants**

A total of 118 participants completed Experiment 4 and were randomly assigned to either the JOL group (*n* = 40), the no-JOL group (*n* = 39), or the frequency judgment group (*n* = 39). All were recruited from The University of Southern Mississippi’s undergraduate research pool and completed the study online in exchange for partial course credit. Participants were all native English speakers and reported normal or corrected-to-normal vision.

**Materials and Procedure**

Experiment 4 used the same materials and followed the general procedure of Experiment 1 with one exception. In addition to the JOL and no-JOL groups, Experiment 4 included a frequency-judgment group in which participants were asked to rate the likelihood in which the cue and target items would appear together in everyday language. The frequency judgment task utilized the same 0-100 rating scale employed by the JOL task in which higher ratings corresponded to more frequent occurrences. Both JOLs and frequency judgments were made concurrently with study such that participants typed their ratings while the pairs were displayed on the screen. Thus, the only difference between the two tasks was the focus of the judgment.

**Results**

The top panel of Figure 4 compares mean JOL ratings and cued-recall rates for each pair type for participants completing the JOL task at encoding, while the bottom panel reports mean recall rates as function of encoding group and pair type. First, to test for the illusion of competence in the JOL group, a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 2 (Measure: JOL vs. Recall) repeated measures ANOVA was used. As expected, this analysis revealed a main effect of Pair Type, *F*(3, 117) = 293.33, *MSE* = 151.31, *ηp*2 = .88, following the same pattern reported in the previous two experiments. JOLs/recall rates were highest for forward pairs (68.29), followed by symmetrical pairs (65.73), backward pairs (47.56), and lowest for unrelated items (17.14). All comparisons differed statistically, *t*s ≥ 2.38, *d*s ≥ 0.18. JOL ratings were only marginally greater than cued-recall rates (52.25 vs. 47.11), *F*(1, 39) = 3.56, *MSE* = 590.62, *p* = .07, *ηp*2 = .08, *p*BIC = .53, however a significant interaction confirmed the presence of an illusion of competence, *F*(3, 117) = 57.32, *MSE* = 68.40, *ηp*2 = .59. For backward pairs, JOLs greatly exceeded subsequent cued-recall rates (59.69 vs. 35.44), *t*(39) = 6.79, *SEM* = 3.69, *d* = 1.27. However, for unrelated pairs, the illusion of competence did not occur, as JOLs and recall were equivalent (16.77 vs. 17.53), *t* < 1, *p*BIC = .86, and this equivalence was also found on symmetrical pairs, (68.54 vs. 62.91), *t*(39) = 1.69, *SEM* = 3.44, *p* = .10, *p*BIC = .61. Finally, as found in Experiment 1, an underestimation pattern was found for forward pairs in which JOLs were generally lower than subsequent recall (64.03 vs 72.57), *t*(39) = 2.90, *SEM* = 3.04, *d* = 0.52.

Next, we conducted a 4 (Pair Type: Forward vs. Backward vs. Symmetrical vs. Unrelated) × 3 (Study Group: JOL vs. Frequency vs. No-JOL) ANOVA to evaluate reactivity effects. An effect of Pair Type was detected, *F*(3, 348) = 590.71, *MSE* = 99.13, *ηp*2 = 0.84, indicating that correct recall was highest for forward pairs (62.94), followed by symmetrical pairs (56.13), backward pairs (29.97), and lowest for unrelated pairs (15.31). Differences were significant across all comparisons, *t*s ≥ 10.80, *d*s ≥ 0.79. An effect Study Group was also found, *F*(2, 116) = 6.00, *MSE* = 1205.07, *p* = .003, *ηp*2 = .12, indicating that correct recall was highest when participants made JOLs (47.13) and frequency judgments (43.30) relative to the no-JOL control group (32.66). All comparisons were significant, *t*s ≥ 2.97, *d*s ≥ 0.67, except for the JOL and frequency groups, *t* < 1, *p*bic = .86.

Critically, a significant interaction was found, *F*(6, 348) = 12.34, *MSE* = 1205.07, *ηp*2 = .17. Follow-up tests indicated that for forward pairs, correct recall in both the JOL (72.57) and frequency judgment (66.58) groups exceeded that of the no-JOL group (49.42). All comparisons differed, *t*s ≥ 3.91, *d*s ≥ 0.88, except for the JOL and frequency judgment groups, *t*(76) = 1.50, *SEM* = 4.07, *p* *=* .14, *p*bic = .74. Symmetrical pairs displayed a similar pattern. Recall was greater in the JOL (62.91) and frequency judgement (62.05) groups relative to the no-JOL group (43.27), and again, all comparisons differed *t*s ≥ 4.23, *d*s ≥ 0.96, with the exception of the JOL and frequency judgment groups, *t* < 1, *p*bic = .85. For backward pairs, correct recall in the JOL (35.44) and frequency judgment (31.23) groups were greater than the no-JOL group (23.01). All comparisons differed significantly, *t*s ≥ 1.96, *p*s < .05, except for the JOL and frequency judgment group, which did not differ, *t* < 1, *p*bic = .90. Finally, for unrelated pairs, recall rates were equivalent across the JOL (17.53), frequency judgment (13.34), and no-JOL (14.94) groups, *t*s ≤ 1.02, *p*s ≥ .31, *p*bic ≥ .88. Thus, both JOL ratings and frequency judgments produced statistically equivalent reactivity patterns on correct recall for related pairs but produced no reactivity on unrelated pairs.

**Discussion**

The primary goal of Experiment 4 was to provide further testing of the strategic relational encoding account of JOL reactivity by assessing whether reactivity patterns observed for JOLs and JAMs in Experiment 3 would replicate when participants engaged in a frequency judgment task at encoding. We selected the frequency judgment task because it provided a closer comparison to the JOL task by removing the emphasis on pair relatedness that is inherent to JAMs. Consistent with Experiment 3, reactivity patterns emerged for both JOLs and frequency judgments. Relative to the no-JOL control group, participants completing either the JOL or frequency judgment task at encoding showed increased correct recall for each of the three types of related pairs. These tasks produced no reactivity when participants studied unrelated pairs, indicating that reactivity effects operated selectively as a function of pair relatedness. Importantly, frequency judgments produced reactivity patterns that were comparable to those observed for JAMs in Experiment 3, providing further evidence that memory forecasting is not a requirement for reactivity to occur.

**General Discussion**

The primary goals of this study were twofold. First, Experiment 1 sought to replicate previous work showing that JOLs produce a reactive effect on cued-recall of related targets while comparing these reactivity patterns on forward, backward, and symmetrical paired associates—a novel contribution. Second, Experiments 2-4 were designed to test a strategic relational encoding account of reactivity. In Experiment 2, we gauged JOL reactivity effects relative to a deep relational encoding strategy, while in Experiment 3, JOL reactivity was compared to the JAM task in which participants made relational, non-metacognitive frequency judgments. Experiment 4 provided an additional test of the strategic relational encoding account by comparing JOL reactivity to a frequency judgment task. Collectively, our results indicate that enhanced relational encoding applied to related but not unrelated pairs primarily contributes to these reactivity benefits and, furthermore, that memory predictions via JOLs are not necessary to produce reactivity effects.

Additionally, in each experiment, we tested whether the illusion of competence pattern emerged for participants completing the JOL task as this pattern has not been consistently reported in the JOL reactivity literature (cf. Mitchum et al., 2016). This pattern of JOL overprediction is typically observed when participants provide JOLs for pair types in which the cue does not readily converge upon the target at test (e.g., backward, symmetrical, and unrelated pairs). In contrast, JOLs for forward pairs wherein the cue provides a better predictor of the target at test, generally show better calibration between JOLs and recall. Consistent with prior studies, a general illusion of competence pattern emerged across experiments in which participants overpredicted recall of backward, symmetrical, and unrelated pairs in the JOL group. For forward pairs, however, JOLs were generally well calibrated with later recall performance, though a pattern of underestimation emerged for forward pairs in Experiments 1 and 4. Finally, in Experiment 4, the illusion of competence did not extend to symmetrical and unrelated pairs, though it still occurred for backward pairs.

Regarding reactivity, Experiment 1 found evidence of positive JOL reactivity on forward pairs that was consistent with previous work by Soderstrom et al. (2015) and Janes et al. (2018), while extending this pattern to include backward and symmetrical pairs. Importantly, these reactivity patterns occurred using pairs that were engineered to control for lexical and semantic item effects, including associative strength that could potentially influence correct recall. The positive reactivity pattern found across related pair types indicates that the associative direction of cue-target pairs does not have an effect on reactivity. Instead, the mere presence of association is likely sufficient to facilitate relational encoding of related pairs. For unrelated pairs however, no reactivity pattern was found as recall was equivalent between the JOL and no-JOL groups. The discrepancy in reactivity for related and unrelated pairs suggests that JOL participants engage in strategic relational encoding of related pair types. As we discuss further below, previous researchers have proposed a similar strategy-based account (e.g., changed-goal hypothesis; Mitchum et al., 2016), but this account does not predict a null reactivity effect on unrelated pairs. Instead, we suggested that positive reactivity of related pairs reflected strategic relational encoding in which participants emphasized the relational characteristics of related pairs at study, facilitating subsequent recall.

To test this account, Experiment 2 compared a relational encoding task in which participants were explicitly instructed to relate all cue-target pairs together at study. Relative to both a no-JOL and a shallow encoding control task, relational encoding produced the same positive reactivity pattern on related pairs as participants who completed the JOL task. Unlike the JOL task, however, the positive reactivity of relational processing was not restricted to related targets as recall of unrelated targets was also greater relative to the no-JOL control group. This latter pattern was unsurprising given participants were instructed to utilize relational encoding for all pair types. Finally, the shallow-vowel counting task did not induce reactivity, suggesting that the qualitative aspects of the encoding task were a driving factor of reactivity relative to merely having participants engage in an additional task at study.

To gauge the strategic component of the relational encoding account, Experiment 3 compared the JOL and no-JOL groups to the JAM task, which required participants to provide relatedness judgments for cue-target pairs. This task was selected as it allowed for processing of the relational characteristics of study pairs without explicit instruction to encode all study pairs using a relational strategy as in Experiment 2. Moreover, the JAM task utilized the same rating scale as the JOL task. The JAM task was therefore closely resembled the JOL task to allow for strategic use of relational encoding but did not require that participants forecast later recall performance. Experiment 3 found equivalent positive reactivity on related pairs when compared to the JOL task and critically, no reactivity was found on unrelated pairs, indicating that reactivity patterns are not exclusive to JOLs and that likely reflect use of strategic relational encoding.

Finally, Experiment 4 compared the JOL and no-JOL groups to a frequency-judgment task in which participants were required to estimate the frequency in which the cue-target pair would co-occur in the English language. Like the JAM task used in Experiment 3, the frequency-judgment task provided an additional test of the strategic relational encoding account as it allowed processing of pair relatedness without explicit relational instructions. However, relative to JAMs, frequency judgments do not emphasize the associative characteristics of cue-target pairs. Like the JAM task used in Experiment 3, frequency judgments showed the same positive reactivity on related pairs as the JOL task, and critically, no reactivity was found on unrelated pairs. The extension of this finding to frequency judgments provides further evidence that reactivity patterns are not limited to JOLs and supports evidence that memory forecasting is not a requirement for reactivity to occur.

**A Case for Strategic Relational Encoding**

As reviewed in the Introduction, one account of JOL reactivity is the changed-goal hypothesis (Mitchum et al., 2016). As per this hypothesis, having participants provide JOLs at study increases participants’ awareness of item difficulty, and as a result, participants will modify their study goals (and therefore, their encoding) to prioritize learning of pairs perceived as easy to remember at the expense of more difficult pairs. Because related pairs are generally viewed as easier to learn, the changed-goal hypothesis posits that providing JOLs will strategically produce positive reactivity for forward, backward, and symmetrical pairs and negative reactivity for more difficult unrelated pairs. However, previous research (e.g., Double et al., 2018; Janes et al., 2018; Soderstrom et al., 2015) has only reported positive reactivity for related pairs and the absence of negative reactivity for unrelated pairs. In the current study, all four experiments similarly found positive reactivity for related pairs and no negative reactivity for unrelated pairs, providing further evidence that participants are unlikely to alter their study goals in a way that produces a cost to unrelated pairs.

Soderstrom et al. (2015) proposed that JOLs will induce reactivity when two criteria are met. First, the JOL task must strengthen cues that inform JOLs (i.e., such as pair relatedness) and second, the same cues must be available at test (i.e., such as a cued-recall test in which the desired target can be triggered by the presentation of the cue). To test this account, Myers et al. (2020) examined whether the reactive effects of JOLs extended to recognition and free recall tests, as these test types do not present participants with the cue item at test and are therefore less dependent on the cues activated by the JOL task at encoding. For both cued-recall and recognition testing, positive reactivity was found on related pairs, but negative reactivity was not found on unrelated pairs, replicating reactivity patterns generally reported for cued-recall (e.g., Janes et al., 2018; Soderstrom et al., 2015) and, furthermore, replicating reactivity patterns that emerged across each of our four experiments. Meyer’s et al.’s (2020) extension of this pattern to recognition memory provides support for Soderstrom et al.’s first criterion that the JOL task strengthens cue-target associations. However, because this pattern was also shown to replicate using recognition testing—a paradigm in which cues are unavailable at retrieval—Soderstrom et al.’s second claim regarding the presence of test cues as a requirement for reactivity was not upheld. Instead, JOL reactivity appears to be driven primarily by relational encoding, which is applied selectively to pairs as a function of pair relatedness. Thus, the present study is consistent with previous studies which have indicated that JOL reactivity is found on related pairs and further establishes that the strategic use of relational processing contributes to JOL reactivity.

Also of note, our experiments indicate that reactivity patterns are not unique to JOLs. Because JOLs call attention to pair relatedness (which is a strong predictor of cued-recall performance; Maxwell & Buchanan, 2020), relatedness cues may become more salient relative to participants in a no-JOL control. Based on this account, reactivity would be expected to occur whenever participants engage in tasks that encourage the use of a relational strategy at encoding and when these tasks include study items that differ in their relatedness. Results from Experiments 2-4 support this claim, as relational encoding (Experiment 2), JAMs (Experiment 3), and frequency judgments (Experiment 4) each produced similar reactivity patterns for related pairs relative to the JOL group. Furthermore, the similarity of reactivity patterns between the JOLs and both JAMs and frequency judgments suggests that each task taps into similar underlying relational encoding processes. Based on Koriat’s (1997) cue-utilization framework, both JOLs and frequency judgments tune participants to specific *intrinsic* cues about the study pairs, providing them with information about inherent properties of the studied material (i.e., pair relatedness). Thus, cued-recall performance is enhanced whenever the encoding task draws attention to the relatedness between studied items, regardless of whether this is done explicitly (e.g., relational study instructions) or implicitly (e.g., JOLs, JAMs, frequency judgments, etc.). However, because this occurred indirectly in Experiments 3 and 4 (as neither the JOL, JAM, or frequency judgment tasks explicitly instructed participants to relate items together at study), only related items receive a memory boost when judged. As such, reactive effects are not generally observed unrelated items unless the task explicitly instructs participants to relate all pairs together.

Our strategic relational encoding account is consistent with previous work on metamemory and strategy use. For example, in their unifying framework of metamemory, Nelson and Narens (1990) posited that participants are able to adjust their encoding strategies based on cues inherent to the stimuli (i.e., engaging in monitoring). Because pair relatedness is a salient cue of future recall performance, it is likely that these relatedness cues trigger participants’ changes in study strategy. Thus, only related pairs are processed using a relational encoding strategy, as participants modify their study strategy whenever they encounter this pair type. This results in a memory boost for related items that receive additional relational processing at encoding while unrelated pairs show no benefit.

Finally, although our proposed account of reactivity is based on strategic relational encoding, the present study does not directly assess whether participants are engaging in relational encoding while providing JOLs. Instead, we rely upon comparisons to similar relational tasks in Experiments 2-4 as a means of triangulating encoding processing (see Huff & Bodner, 2013; Meade, Klein, & Fernandes, 2020, for similar comparison approaches). Second, our experiments did not include any online measures of strategic encoding at either study or test. While it has been well documented within the metacognitive literature that participants engage in strategic encoding both when acquiring new knowledge and when processing metamemorial information (e.g., Hertzog & Dunlosky. 2004; Nelson & Narens, 1990), our study did not explicitly assess whether participants were altering study strategies as a function of pair type. Rather, strategic changes of encoding strategy were inferred based on differences in cued-recall rates. Future research could utilize more direct measures such as having participants report the type of encoding used during study as a function of pair type which could also indicate any encoding changes which would be consistent with a strategy change.

**Conclusion**

The present study provides further examination of JOL reactivity and its underlying mechanisms. The use of multiple associative pair types provided us with a more precise test of negative reactivity, the changed-goal hypothesis, and allowed us to test whether different associative pair types produce the same reactive benefits as forward associates. Overall, we found that the reactive benefits of JOLs can extend to both backward and symmetrical pairs. Importantly, our findings from Experiments 3 and 4 indicate that reactive effects associated with JOLs are not exclusive to JOLs and extend to other types of rating tasks that both do and do not emphasize the associative characteristics of cue-target pairs. Our experiments demonstrate that reactivity is driven by strategic allocation relational encoding towards related pairs and that memory forecasting from JOLs are not a prerequisite for reactivity.

**Open Practices Statement**

The data for all experiments have been made available at https://osf.io/8yvn3/. None of the experiments were preregistered.

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Footnotes

1 For completeness, we further analyzed the effect of block order in Experiments 1-3. No interactions with block were found in Experiment 1 or Experiment 3 (*F*s < 2.50, *p*s > .06, *p*BICs > .99), however block did interact with pair type in Experiment 2, *F*(3, 489) = 879.21, *MSE* = 83.64, *ηp*2 = 0.01, though all other interactions with block were not significant (*F*s < 1.63, *p*s > .10, *p*BICs > .99). Post-hoc *t*-tests revealed that correct recall of backward pairs was numerically higher in block 1 (23.66) than block 2 (21.07), however, this comparison failed to reach conventional significance, *t*(165) = 1.77, *SEM* = 1.46, *p* = .08, *p*BIC = .81. All other comparisons were non-significant (*t*s < 1, *p*BICs > .89). Furthermore, the same general pattern of reactivity was detected in Experiment 2 after controlling for block order, indicating order did not contribute to the reactivity patterns reported.

2 Due to the COVID-19 pandemic, data collection was shifted online to Prolific partway through Experiment 2. The forty participants in the no-JOL group were recruited through Prolific. Additionally, 20 participants in the relational group, 19 participants in the shallow group, and 2 participants in the JOL group were recruited via Prolific. For completeness, we note that mean correct recall did not differ between the no-JOL group in Experiment 2 and the undergraduate sample completing the same task in Experiment 3 (28.11 vs. 32.66; *t*(69) = 1.50, *SEM* = 3.08, *p* = .14, *p*BIC = .74). Additionally, within Experiment 2, recall did not differ between the undergraduate and Prolific samples in the relational group (44.81 vs. 38.05; *t*(43) < 1, *SEM* = 7.11, *p* = .33, *p*BIC = .79) or the vowel counting group (36.56 vs. 30.47; *t*(43) = 1.07, *SEM* = 5.87, *p* = .29, *p*BIC = .80). Thus, recall performance and JOL responses did not appear to differ as a function of participant source.

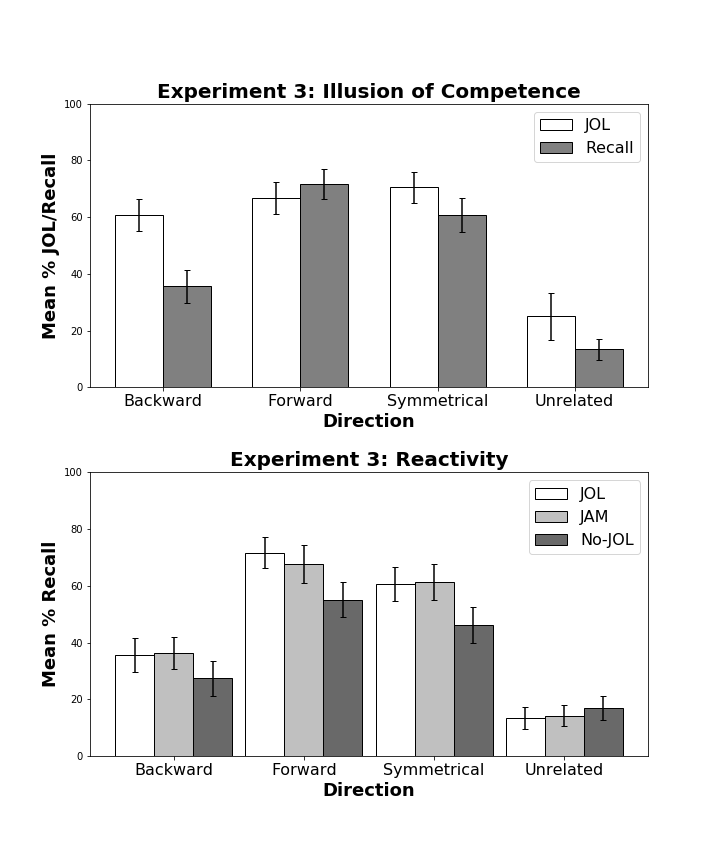
3 As with Experiment 2, data collection in Experiment 3 was shifted online to Prolific midway through data collection in response to COVID-19. In addition to the 70 participants recruited through the University of Southern Mississippi’s undergraduate pool, 28 participants were recruited through Prolific, with 11 completing the JOL task, 10 completing the JAM task, and 7 assigned to the no-JOL control group. Overall, mean recall did not differ between the Prolific or USM groups for the JOL task (44.06 vs 47.95), JAM task (46.09 vs 42.00), or the no-JOL control task (35.85 vs 38.66), all *t*s < 1, *p*s≤ .48, *p*BICs ≥ .78. Thus, participant performance did not appear to be influenced by recruitment source.

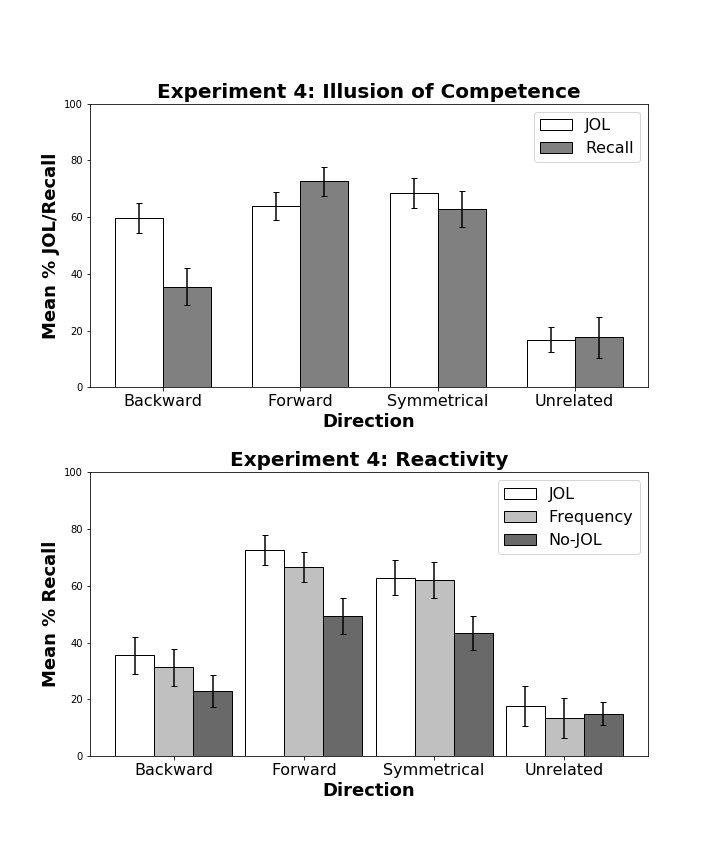


*Figure 1.* Comparison of mean JOL ratings and recall rates in the JOL encoding group (top panel) and recall rates in the JOL and No-JOL groups (bottom panel). Error bars represent 95% confidence intervals.



*Figure 2.* Comparison of mean JOL ratings and recall rates in the JOL encoding group (top panel) and recall rates in the JOL, Relational Encoding, Vowel Counting, and No-JOL groups (bottom panel). Error bars represent 95% confidence intervals.

*Figure 3.* Comparison of mean JOL ratings and recall rates in the JOL encoding group (top panel) and recall rates in the JOL, JAM, and No-JOL groups (bottom panel). Error bars represent 95% confidence intervals.



*Figure 4.* Comparison of mean JOL ratings and recall rates in the JOL encoding group (top panel) and recall rates in the JOL, Frequency judgment, and No-JOL groups (bottom panel). Error bars represent 95% confidence intervals.

**Appendix**

Table A1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Condition | Variable | *M* | *SD* | *Min.* | *Max.* |
| Forward | FAS | .37 | .21 | .05 | .81 |
|  | BAS | .00 | .00 | .00 | .00 |
| Backward | FAS | .00 | .00 | .00 | .00 |
|  | BAS | .37 | .21 | .05 | .81 |
| Symmetrical | FAS | .19 | .13 | .01 | .46 |
|  | BAS | .19 | .13 | .02 | .52 |

*Mean Associative Strength Summary Statistics Forward, Backward, and Symmetrical Pairs.*

*Note.* FAS (forward associative strength) and BAS (backward associative strength) values for unrelated pairs as these items share zero associative overlap.

Table A2

*Summary Statistics for Cue and Target Concreteness, Length, and Frequency Item Properties as a Function of Pair Type.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pair Type | Position | Variable | *M* | *SD* |
| Forward | Cue | Concreteness | 4.97 | 1.22 |
|  |  | Length | 6.20 | 1.86 |
|  |  | Frequency | 3.74 | 0.67 |
|  | Target | Concreteness | 4.96 | 1.14 |
|  |  | Length | 4.46 | 1.27 |
|  |  | Frequency | 2.49 | 0.63 |
| Backward | Cue | Concreteness | 4.96 | 1.14 |
|  |  | Length | 4.46 | 1.27 |
|  |  | Frequency | 2.49 | 0.63 |
|  | Target | Concreteness | 4.97 | 1.22 |
|  |  | Length | 6.20 | 1.86 |
|  |  | Frequency | 3.74 | 0.67 |
| Symmetrical | Cue/Target | Concreteness | 4.70 | 1.38 |
|  |  | Length | 5.21 | 1.94 |
|  |  | Frequency | 3.23 | 0.67 |
| Unrelated | Cue/Target | Concreteness | 4.63 | 128 |
|  |  | Length | 5.21 | 1.52 |
|  |  | Frequency | 2.49 | 0.85 |

*Notes.* Frequency is measured using SUBTLEX word frequency measure (Brysbaert & New, 2009). Concreteness and length were taken from the English Lexicon Project (Balota et al., 2007).

Table A3

*Comparison of Mean JOL Ratings and Correct Recall Percentages across Pair Types for the JOL Group in Experiments 1-4.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Experiment | Task | Pair Type | *M* | *95% CI* | F | B | S |
| Exp. 1 | JOL | Forward | 60.87 | 3.85 |  |  |  |
|  |  | Backward | 55.18 | 4.07 | 0.45\* |  |  |
|  |  | Symmetrical | 64.84 | 3.75 | 0.33\* | 0.77\* |  |
|  |  | Unrelated | 19.43 | 4.76 | 3.00\* | 2.53\* | 3.33\* |
|  | Recall | Forward | 69.34 | 5.39 |  |  |  |
|  |  | Backward | 31.67 | 5.30 | 2.21\* |  |  |
|  |  | Symmetrical | 57.78 | 5.59 | 0.66\* | 1.51\* |  |
|  |  | Unrelated | 8.85 | 2.50 | 4.51\* | 1.72\* | 3.54\* |
| Exp. 2 | JOL | Forward | 67.63 | 3.98 |  |  |  |
|  |  | Backward | 62.18 | 4.24 | 0.39\* |  |  |
|  |  | Symmetrical | 71.89 | 4.21 | 0.31\* | 0.72\* |  |
|  |  | Unrelated | 22.30 | 4.98 | 2.99\* | 3.30\* | 3.98\* |
|  | Recall | Forward | 63.78 | 4.49 |  |  |  |
|  |  | Backward | 26.60 | 4.21 | 2.68\* |  |  |
|  |  | Symmetrical | 54.17 | 5.06 | 0.63\* | 1.85\* |  |
|  |  | Unrelated | 9.87 | 2.85 | 4.50\* | 1.46\* | 3.39\* |
| Exp. 3 | JOL | Forward | 66.25 | 5.68 |  |  |  |
|  |  | Backward | 60.15 | 5.75 | 0.36\* |  |  |
|  |  | Symmetrical | 70.14 | 5.49 | 0.23\* | 0.59\* |  |
|  |  | Unrelated | 23.94 | 8.34 | 1.99\* | 1.70\* | 2.20\* |
|  | Recall | Forward | 71.74 | 5.33 |  |  |  |
|  |  | Backward | 35.61 | 5.71 | 2.22\* |  |  |
|  |  | Symmetrical | 60.68 | 5.93 | 0.67\* | 1.46\* |  |
|  |  | Unrelated | 13.41 | 3.75 | 4.32\* | 1.56\* | 3.25\* |
| Exp. 4 | JOL | Forward | 64.03 | 4.98 |  |  |  |
|  |  | Backward | 59.69 | 5.17 | 0.26\* |  |  |
|  |  | Symmetrical | 68.54 | 5.16 | 0.28\* | 0.53\* |  |
|  |  | Unrelated | 16.77 | 4.42 | 3.11\* | 2.77\* | 3.34\* |
|  | Recall | Forward | 72.57 | 5.20 |  |  |  |
|  |  | Backward | 35.44 | 6.52 | 1.95\* |  |  |
|  |  | Symmetrical | 62.91 | 6.21 | 0.52\* | 1.33\* |  |
|  |  | Unrelated | 17.53 | 7.15 | 3.25\* | 0.80\* | 2.09\* |

*Note.* The three right-most columns indicate Cohen’s *d* effect sizes for post-hoc comparisons, \* = *p* < .05.

Table A4

*Comparisons of Mean Recall Percentages for each Pair Type in Experiments 1-4.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Experiment | Encoding Task | Pair Type | *M* | *95% CI* | F | B | S |
| Exp. 1 | JOL | Forward | 69.34 | 5.39 |  |  |  |
|  |  | Backward | 31.67 | 5.30 | 2.21\* |  |  |
|  |  | Symmetrical | 57.78 | 5.59 | 0.66\* | 1.51\* |  |
|  |  | Unrelated | 8.85 | 2.50 | 4.51\* | 1.72\* | 3.54\* |
|  | No-JOL | Forward | 48.08 | 5.21 |  |  |  |
|  |  | Backward | 16.09 | 3.30 | 2.30\* |  |  |
|  |  | Symmetrical | 36.03 | 4.97 | 0.74\* | 1.48\* |  |
|  |  | Unrelated | 9.68 | 3.16 | 2.80\* | 0.66\* | 1.99\* |
| Exp. 2 | JOL | Forward | 63.78 | 4.49 |  |  |  |
|  |  | Backward | 26.60 | 4.21 | 2.68\* |  |  |
|  |  | Symmetrical | 54.17 | 5.06 | 0.63\* | 1.85\* |  |
|  |  | Unrelated | 9.87 | 2.85 | 4.50\* | 1.46\* | 3.39\* |
|  | Relational | Forward | 58.17 | 6.69 |  |  |  |
|  |  | Backward | 30.89 | 7.56 | 1.12\* |  |  |
|  |  | Symmetrical | 50.06 | 6.73 | 0.35 | 0.78\* |  |
|  |  | Unrelated | 25.11 | 7.49 | 1.36\* | 0.22 | 1.02\* |
|  | Vowel | Forward | 39.19 | 6.72 |  |  |  |
|  |  | Backward | 14.13 | 5.68 | 1.20\* |  |  |
|  |  | Symmetrical | 29.83 | 6.37 | 0.42 | 0.78\* |  |
|  |  | Unrelated | 9.59 | 5.47 | 1.44\* | 0.24 | 1.02\* |
|  | No-JOL | Forward | 48.06 | 4.63 |  |  |  |
|  |  | Backward | 17.13 | 3.45 | 2.34\* |  |  |
|  |  | Symmetrical | 38.13 | 4.65 | 0.66\* | 1.59\* |  |
|  |  | Unrelated | 9.13 | 3.16 | 3.04\* | 0.75\* | 2.26\* |
| Exp. 3 | JOL | Forward | 71.74 | 5.53 |  |  |  |
|  |  | Backward | 35.61 | 5.75 | 2.22\* |  |  |
|  |  | Symmetrical | 60.68 | 5.93 | 0.67\* | 1.46\* |  |
|  |  | Unrelated | 13.41 | 3.75 | 4.32\* | 1.56\* | 3.25\* |
|  | JAM | Forward | 67.58 | 6.74 |  |  |  |
|  |  | Backward | 36.36 | 5.71 | 1.71\* |  |  |
|  |  | Symmetrical | 61.29 | 6.42 | 0.32 | 1.40\* |  |
|  |  | Unrelated | 14.68 | 3.65 | 3.36\* | 1.58\* | 3.08\* |
|  | No-JOL | Forward | 55.16 | 6.28 |  |  |  |
|  |  | Backward | 27.34 | 6.13 | 1.55\* |  |  |
|  |  | Symmetrical | 46.41 | 6.36 | 0.48 | 1.06\* |  |
|  |  | Unrelated | 16.95 | 4.24 | 2.28\* | 0.68\* | 1.89\* |
| Exp. 4 | JOL | Forward | 72.57 | 5.20 |  |  |  |
|  |  | Backward | 35.44 | 6.52 | 1.95\* |  |  |
|  |  | Symmetrical | 62.91 | 6.21 | 0.52\* | 1.33\* |  |
|  |  | Unrelated | 17.53 | 7.15 | 3.25\* | 0.80\* | 2.09\* |
|  | Frequency | Forward | 66.58 | 5.87 |  |  |  |
|  |  | Backward | 31.23 | 6.14 | 1.85\* |  |  |
|  |  | Symmetrical | 62.05 | 6.21 | 0.23 | 1.56\* |  |
|  |  | Unrelated | 13.34 | 4.06 | 3.31\* | 1.08\* | 2.91\* |
|  | No-JOL | Forward | 49.42 | 6.29 |  |  |  |
|  |  | Backward | 23.01 | 5.60 | 1.39\* |  |  |
|  |  | Symmetrical | 43.27 | 6.06 | 0.31 | 1.09\* |  |
|  |  | Unrelated | 14.94 | 4.09 | 2.04\* | 0.52\* | 1.72\* |

*Note.* The three right-most columns indicate Cohen’s *d* effect sizes for post-hoc comparisons, \* = *p* < .05.