Judgments of Learning Facilitate Cued-Recall of Semantically Mediated Paired-Associates

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**Author Note**

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**Abstract**

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Judgments of learning (JOLs) provide important insights regarding the learning process. JOLs can be elicited for a variety of stimuli (e.g., faces; Hourihan, Benjamin, & Liu, 2012; educational text passages; Ariel, Karpicke, Witherby, & Tauber, 2021); however, they are often provided for cue-target word pairs (e.g., mouse – cheese). Within this context, JOLs are typically framed as the percent likelihood that individuals will correctly recall a pair’s target on a later memory test if cued by the first word (see Rhodes, 2016). Although JOLs have commonly been treated as neutral measures with little effect on memory, a decade of research has consistently shown that JOLs are *reactive* on memory for cue-target pairs, particularly whenparticipants provide them concurrently with or immediately following study (e.g., Janes, Rivers, & Dunlosky, 2018; Maxwell & Huff, 2022; 2023; Mitchum, Kelley, & Fox, 2016; Soderstrom, Clark, Halamish, & Bjork, 2015; see Double, Birney, & Walker, 2018 for review). However, these studies have consistently found that JOL reactivity patterns observed on cue-target pairs are moderated by pair relatedness. Specifically, providing JOLs at encoding benefits cued-recall of related pairs (i.e., *positive reactivity*) but produces no benefits or can even produce memory costs on unrelated pairs (i.e., *negative reactivity*; but see Mitchum et al., 2016; who reported no reactivity on related pairs and negative reactivity on unrelated pairs). As such, merely providing JOLs at encoding is sufficient to modify participants’ memory for studied pairs, though inherent properties of the pairs can modify direction of this effect.

Several theories have been proposed to explain why JOLs often improve cued-recall of cue-target word pairs and, specifically, why this effect is moderated by pair relatedness. One account which has received significant attention in the literature is the cue-strengthening account (Soderstrom et al., 2015). This account, based on Koriat’s (1997) cue-utilization framework, posits that for JOLs to be reactive on memory, the act of making JOLs must first strengthen intrinsic cues about each pair, which provide indicators of future recall performance and are used to inform the magnitude of participants’ JOLs. By strengthening these cues, JOLs improve memory for studied items compared to a no-JOL control task like silent reading. However, for memory benefits to occur, the method of testing must be sensitive to the specific cues being strengthened via JOLs. Thus, based on this account, JOL reactivity requires a match between cues strengthened at encoding and the method by which memory is assessed.

Because the cue-strengthening account explains the general pattern of reactivity that is often observed on cue-target word pairs (i.e., positive reactivity on related pairs but no reactivity or negative reactivity on unrelated pairs), recent studies investigating the mechanisms behind JOL reactivity have directly tested this account. Overall, findings from these studies largely support the cue-strengthening account and, specifically, its claim that JOL reactivity requires a match between encoding-based cues and the method by which memory is assessed. For example, Myers, Rhodes, and Hausman (2020) found that JOL reactivity patterns observed on cue-target pairs with cued-recall testing did not extend to free-recall in which cues were unavailable at test. This finding was later replicated by Chang and Brainerd (2023) who similarly found no memorial benefits of JOLs on free-recall. Separately, other studies have sought to identify the specific cues which JOLs are purported to strengthen. Because JOL reactivity studies often have participants study mixed lists of related and unrelated cue-target pairs, much emphasis has been placed on the potential for JOLs to strengthen relatedness cues, given that relatedness cues are highly salient markers of later remembering and thus are likely to inform the magnitude of participants’ JOLs (see Koriat, 1997). Thus, although participants can potentially base their JOLs on a variety of intrinsic cues (e.g., concreteness, item-frequency), the presence of strong relatedness cues likely mitigates other cues which could also potentially contribute to reactivity.

Given the link between cue-strengthening and pre-existing cue-target relations, JOL reactivity studies have begun exploring the extent to which these relations contribute to positive reactivity. For example, Maxwell and Huff (2022) compared JOLs to several other non-metacognitive encoding tasks and found that positive JOL reactivity patterns on related cue-target pairs approximated memory benefits from judgments of associative memory (JAMs; Experiment 2; see Maki, 2007), frequency of co-occurrence judgments (Experiment 3), and, importantly, an explicit relational encoding task in which participants where directly instructed to relate all word pairs together at encoding. To explain these findings, the authors proposed a relational encoding account of JOL reactivity. Based on this account, the providing JOLs at encoding specifically encourage participants to engage in relational encoding at study. This in turn facilitates memory for related pairs by strengthening pre-existing cue-target relations that are inherent to this pair. As such, related cue-target pairs show a memory advantage at test. However, this memory advantage does not extend to unrelated pairs given they lack pre-existing cue-target relations. As a result, related but not unrelated pairs show a memorial benefit at test. Thus, the relational encoding account is consistent with the cue-strengthening account and explains the mechanisms by which cue-strengthening occurs.

Other studies investigating JOL reactivity on cue-target word pairs have similarly produced findings that are consistent with a relational encoding account. Recently, Rivers, Janes, Dunlosky, Witherby, and Tauber (2023) had participants complete a questionnaire following either silently reading or providing JOLs for related and unrelated cue-target word pairs. Consistent with a relational encoding account of reactivity, a majority of their participants (68.7% in Experiment 1 and 80.4% in Experiment 2) indicated that perceived cue-target relations were the strongest factor influencing their JOLs. Additionally, Halamish and Undorf (2023) tested for JOL reactivity using related, identical, and unrelated cue-target pairs and, at test, had participants indicate whether a previously studied target had been paired with a related, identical, or unrelated cue at encoding. While both related and identical pairs showed positive reactivity compared to unrelated pairs, relatedness judgments elicited at test were most accurate for related pairs. Thus, there is growing evidence that pre-existing cue-target relations are strongly linked to positive reactivity observed on cued-recall of word pairs.

**Positive JOL Reactivity in the Absence of Strong-Relatedness Cues**

As noted above, there is growing evidence that positive JOL reactivity on cue-target pairs reflects contributions from a relational encoding process. Critically, however, the specific link between relational encoding and cue-strengthening processes remains unclear. Moreover, although both the cue-strengthening and relational encoding accounts propose that cue-target relations moderate JOL reactivity, each account emphasizes different aspects of pair relatedness. For example, pair relatedness can be divided into *a priori* and *a posteriori* relations (see Koriat, 1981). First, a priori relatedness represents the probability that a cue word within a paired-associate would elicit the target as a response and, as such, is best represented by free-association norms (e.g., De Deyne et al., 2019; Nelson, McEvoy, & Schrieber, 2004). This type of relatedness is critical for cued-recall testing, as pairs which are low in a priori relatedness would have targets which are more difficult to retrieve at test. Separately, a posteriori relatedness reflects the degree to which a cue and target are perceived as being related. Thus, JOLs are particularly sensitive to a posteriori associations. Importantly, however, a priori and a posteriori associations are not mutually exclusive, and related cue-target pairs may be high in one or both relatedness types. Regarding JOL reactivity, the cue-strengthening account predicts that a posteriori relatedness primarily drives positive JOL reactivity on related cue-target pairs. This is because, as per this account, making JOLs primarily strengthens perceptible relatedness cues which inform the magnitude of participants’ JOLs. Separately, the relational encoding account of reactivity posits that a priori relatedness is the primary contributor to positive JOL reactivity, as this account states that JOLs strengthen pre-existing, underlying relations between cue and target.

To test between the cue-strengthening and relational encoding accounts of reactivity, researchers can manipulate the type of relations between paired items. For example, *backward paired-associates* can be generated by taking asymmetrical paired-associates presented in the forward direction (e.g., *Text* – *Book*) and simply flipping the cue and target’s order (e.g., *Book* – *Text*). Unlike forward associates in which the target is high probability response to the cue and thus contains a direct, a priori relation, backward pairs’ targets are unrelated to the cue based on free-association norms. However, thematically, these items are perceived as similar, and thus backward associates have strong a posteriori relatedness (i.e., participants perceive backward associates as being related at encoding). For example, participants generally assign JOLs to backward associates which approximate those given to forward associates, even though later memory for forward associates greatly exceeds backward associates (i.e., the illusion of competence; see Koriat & Bjork, 2005; 2006). However, although a posteriori relatedness cues do not benefit recall of backward associates, positive JOL reactivity still extends to this pair type (see Maxwell & Huff, 2022; 2023). Thus, JOL reactivity still occurs even when strengthened relatedness cues are not diagnostic of later memory.

The finding that positive reactivity readily extends to backward associates suggests that JOLs may strengthen underlying cue-target relations in addition to strengthening a posteriori cues which inform JOLs. Recently, Maxwell and Huff (2024) directly tested this account by assessing whether positive JOL reactivity observed on related cue-target pairs extended to semantically mediated associates (e.g., *beach* – *box*), which appear unrelated at encoding (i.e., they lack a posteriori relatedness) but are indirectly related via a non-presented mediator (e.g., *sand*). Unlike traditional related pairs (e.g., beach – ball), mediated associates do not contain obvious relatedness cues. However, mediated associates still contain a priori relations via the non-presented mediator. Thus, by including mediated paired-associates, participants studied a pair type in which items were indirectly related via the non-presented mediator yet lacked a posteriori relatedness cues to inform the magnitude of their JOLs.

The cue-strengthening and relational encoding accounts make diverging predictions regarding JOL reactivity on mediated paired-associates. First, the cue-strengthening account predicts no memory benefit for mediated paired-associates, given the lack of discernable relatedness cues for JOLs to strengthen (i.e., mediated pairs appear unrelated at encoding, even though they are indirectly linked via the non-presented mediator). Alternatively, the relational encoding account predicts a memory improvement for all related pair types, regardless of whether pairs contain strong relatedness cues. Consistent with this account, Maxwell and Huff found that positive reactivity extended to mediated paired-associates, regardless of whether memory was assessed via cued-recall (Experiment 1) or recognition testing (Experiments 2 and 3). Considered alongside other studies exploring relational encoding and cue-strengthening processes (e.g., Halmish & Undorf, 2023; Maxwell & Huff, 2022; Rivers et al., 2023), there is converging evidence that positive reactivity on related cue-target pairs likely reflects JOLs facilitating processing of a priori cue-target relations.

**The Present Study**

As noted above, findings from prior studies suggest that JOLs specifically encourage processing of pre-existing cue-target relations and, importantly, that this effect can occur even for pair types which lack obvious relatedness cues so long as they share an underlying relation. Critically, Maxwell and Huff’s (2024) finding that positive JOL reactivity patterns extend to cued-recall of semantically mediated pair-associates suggests that simply providing JOLs at encoding likely strengthens pre-existing cue-target relations in addition to strengthening perceptible relatedness cues (i.e., cue-strengthening). However, although the mediated pairs utilized by Maxwell and Huff were designed to appear unrelated at encoding, it may be the case that participants were aware of these pairs’ underlying relations, particularly if they were able to guess the mediator at encoding. As such, the present study further investigated the extent to which positive reactivity extends to mediated paired-associates while providing a stronger test of the relational encoding account of JOL reactivity.

Overall, we first sought to replicate Maxwell and Huff’s (2024) finding that JOLs are reactive on cued-recall of mediated paired-associates (Experiment 1A) while additionally testing whether JOLs would similarly facilitate cued-recall of backward mediated associates (Experiment 1B). Backward mediated associates were generated by reversing the order of mediated paired items (e.g., *lion*-*stripes* becomes *stripes*-*lion*). Importantly, our inclusion of backward mediated associates in Experiment 1B allowed us to mitigate potential effects of participants guessing the mediator, as any potential relatedness cues which participants might derive from correctly guessing the mediator would be poor cues for later recall (see Koriat & Bjork, 2005, Maxwell & Huff, 2021). We then tested whether positive JOL reactivity would extend to double-mediated paired-associates (i.e., pairs mediated through two concepts; see Chwilla & Kolk, 2002), which were presented in the forward (Experiment 2A) and backward directions (Experiment 2B). Thus, by testing whether positive JOL reactivity extended to various types of mediated paired-associates, the present study provided stronger tests of the relational and cue-strengthening accounts of JOL reactivity while also further exploring the extent to which a posteriori relatedness cues are a requisite for JOLs to facilitate cued-recall of paired-associates.

**Experiment 1A: Mediated Paired-Associates**

Experiment 1A sought to replicate previous findings reported by Maxwell and Huff (2024) demonstrating that positive JOL reactivity patterns observed on related paired-associates extend to semantically mediated associates in which the cue and target are indirectly related via a non-presented mediated (e.g., *lion* – *stripes* is mediated through *tiger*). Consistent with previous research (e.g., Maxwell & Huff, 2022; Rivers et al., 2023; Soderstrom et al., 2015), we expected that making JOLs would improve memory for related cue-target pairs relative to participants completing a silent reading control task and, additionally, that this memory benefit would not extend to unrelated pairs. Instead, we anticipated that JOLs would be non-reactive on cued-recall of unrelated pairs. For mediated pairs, we note that the cue-strengthening and relational encoding accounts make diverging predictions. Specifically, because the cue-strengthening account states that JOL reactivity is contingent upon perceptible relatedness cues being strengthened at encoding, this account predicts no memory benefits on mediated pairs. However, as per the relational encoding account, the presence of an indirect relationship is sufficient to produce reactivity. Based on Maxwell and Huff’s (2024) findings, we similarly anticipated that JOLs would facilitate cued-recall of mediated pairs. Thus, findings in Experiment 1A were expected to support a relational encoding account of JOL reactivity.

**Method**

**Participants**

We recruited 135 undergraduate students who completed Experiment 1 online in exchange for partial course credit. Participants were simultaneously recruited from two sources, with 63 recruited from the University of Southern Mississippi and the remaining 72 participants recruited from Midwestern State University. Recruitment was based on an a priori power analyses conducted with *G\*Power 3.1* (Faul, Erdfelder, Buchner, & Lang, 2009) which suggested that 74 particpants would be required to detect small-to-medium main effects/interactions (*d* = 0.30; *α* = .05, 1 – *β* = .80). However, following the design of Maxwell & Huff (2024), participant recruitment was increased to account for increased variability due to our use of online testing. Participants were randomly assigned to either the JOL or no-JOL encoding groups. We excluded 10 participants from the final dataset due to low recall rates (i.e., < 5%), which suggested that participants did not adhere to task instructions, recall rates > 95% (which implied cheating at test), or for particpants who consistently anchored their JOLs on scale extremes (i.e., only providing JOLs of 0 or 100). As such, our final sample contained responses from 125 participants (*n* JOL = 62; *n* no-JOL group = 63), which was based on Maxwell and Huff’s (2024) Experiment 1 sample size. All participants were native English speakers with normal or corrected-to-normal vision.

**Materials**

Ninety cue-target word pairs were taken from Maxwell and Huff (2024). These pairs included 30 forward associates derived from Nelson et al.’s (2004) free association norms (e.g., *Litter* – *Trash*), 30 unrelated cue-target pairs (e.g., *Maze* – *Phone*), and 30 semantically mediated associates (e.g., *Horse* – *Wheel*) which were taken from Balota and Lorch (1986) and Jones (2010). Pairs were then randomly split into two lists, with the constraint that each list contained 15 of each pair type (i.e., forward, unrelated, and mediated). Thus, each study list contained 45 cue-target pairs. Lists were matched on SUBLTEX frequency (Brysbaert & New, 2009), concreteness, and length and, additionally, forward associates in each list were matched on forward associate strength (FAS; see Tables A1 and A2 in Appendix for stimuli properties). Additionally, each study list began and ended with five additional, non-tested buffer pairs, which accounted for primacy and recency effects. Thus, each list contained 55 cue-target pairs, though only 45 pairs were tested. Finally, we generated two cued-recall tests (one per study list) by taking each cue item from the tested pairs and replacing its target with a question mark (e.g., *Litter* – ?). For completeness, a .csv file containing each study list has been made available via OSF: [LINK].

**Procedure**

Experiment 1A directly followed the design used in Maxwell and Huff’s (2024) Experiment 1. All participants completed the experiment online using Collector, which provides an open-source platform for conducting browser-based psychology experiments (Garcia & Kornell, 2015). After providing informed consent, participants in both encoding groups were informed that they would be presented with a series of word pairs and that their memory for each pair’s target word would be tested at a later time. Participants were additionally informed that pairs would always be constructed such that the cue appeared on the left-hand side and the target would appear on the right. Next, participants who had been randomly assigned to the JOL encoding group then received additional instructions to provide JOLs while completing the study task. JOLs were framed as the probability of successfully recalling the target item at test if prompted by the cue. JOL participants were instructed to provide their ratings using a 0-100 scale, such that higher values denoted a greater probability of correctly retrieving the target at test. Additionally, JOL participants were encouraged to be as accurate as possible when providing JOLs and were discouraged from anchoring on scale extremes (i.e., only providing JOLs or 0 or 100 for most trials). JOL participants provided their ratings concurrently with study, such that JOLs were provided while the cue-target pair was displayed on the computer screen. Separately, participants in the no-JOL control group were instructed to read each pair silently and were also notified of the upcoming memory test. After receiving their respective encoding instructions, both groups began the first study list. List items were randomized for all participants with the exception that all lists began and ended with the same buffer items. Encoding was self-paced, and participants pressed the ENTER key to advance to the next trial in the list.

Following the completion of the first list, participants immediately began a distractor task in which they alphabetized the 50 US states. This task was timed for two minutes and, once this limit was reached, participants immediately began the cued-recall test. This test presented with the first word from each of the previously studied lists which was paired with a question-mark placeholder in leu of the target. Participants were asked to type the missing target from memory. However, if participants could not retrieve the target, they were told that they could advance to the next pair by pressing the ENTER key. This test was self-paced. After completing the cued-recall test, participants immediately began the second block, which was structured the same as the first. As such, all participants completed two study/test cycles. Block order was counterbalanced across participants, and after completing the second block, participants were debriefed. Participants in both encoding groups took approximately 30 minutes to complete the experiment.

**Experiment 1B:** **Backward Mediated Paired-Associates**

Experiment 1B then tested whether positive JOL reactivity observed on mediated paired-associates in Experiment 1A would extend to mediated paired-associates presented in the backward direction. Like forward mediated associates, backward mediated associates similarly contain an indirect link between cue and target. However, by reversing the order of paired items, any potential relatedness cues which participants might perceive due to correctly guessing a pair’s mediator would be poor indicators of later cued-recall performance. This is because mediators in backward pairs are lower probability responses to cue items based on free-association norms. As a result, backward mediated pairs provide a stronger test of the relational encoding account.

Based on previous studies, we again anticipated that positive reactivity would extend to forward associates and that no reactivity would be observed on unrelated cue-target pairs. Additionally, our predictions for backward mediated paired-associates were the same as our predictions for mediated paired-associates in Experiment 1A. Specifically, we anticipated that requiring participants to provide JOLs at encoding would also improve memory for this pair type via relational encoding of the indirect link between cue and target. As such, any reactivity patterns observed in Experiment 1B were expected to be in line with a relational encoding account of JOL reactivity.

**Method**

**Participants**

An additional 118 undergraduate students were recruited from the University of Southern Mississippi and completed Experiment 1B online in exchange for partial course credit. Like Experiment 1A, participants in Experiment 1B were randomly assigned to either the JOL or no-JOL encoding groups. Data screening followed the same criteria outlined in Experiment 1A, and three participants were excluded from the final dataset. Our final sample contained responses from 115 participants (*n* JOL = 56; *n* no-JOL = 59). This sample size was informed by Experiment 1A, and a sensitivity analyses conducted with *G\*Power 3.1* suggested that our final sample was sufficient to detect small main effects/interactions (*d* = 0.24, *α* = .05, 1 – *β* = .80).

**Materials and Procedure**

Participants in Experiment 1B studied the same set of lists presented in Experiment 1A with the following exception. The order of all mediated paired-associates (e.g., lion-stripe) was reversed, such that these associates were mediated in the backward direction (e.g., stripe-lion). All other aspects of the stimuli used in Experiment 1B were identical to the previous experiment, including the use of forward associates and unrelated pairs. Experiment 1B followed the same general procedure as Experiment 1A, and participants took approximately 30 minutes to complete this experiment.

**Results: Experiments 1A and 1B**

Figure 1 displays mean cued recall rates for JOL and no-JOL participants in Experiments 1A (top panel) and 1B (bottom panel). For completeness, all comparisons are reported in the Appendix (Table AX). Prior to conducting our analyses, cued-recall responses were scored in *R* using the *lrd* package (Maxwell, Huff, & Buchanan, 2022), which automates scoring of cued-recall responses while also correcting for potential spelling/grammatical errors. For the following analyses, we set significance at the *p* < .05 level. For concision, *p*-values are only reported for statistically non-significant comparisons. Additionally, all non-significant comparisons include a supplemental Bayesian estimate of strength of evidence supporting the null hypothesis (*p*BIC; see Masson, 2011; Wagenmakers, 2007), which estimates the probability of the null hypotheses being retained. Finally, for all significant comparisons analyses of variance (ANOVAs) and *t*-tests, we report partial eta squared (*ηp*2) and Cohen’s *d* effect size indices, respectively.

**Experiment 1A**

To test for JOL reactivity patterns on cued-recall, the data was analyzed via a 2 (Encoding Group: JOL vs. No-JOL) 3 (Pair Type: Forward vs. Mediated vs. Unrelated) mixed measures ANOVA. Overall, a significant main effect of Encoding Group emerged as, collapsed across Pair Types, mean correct cued-recall for participants in the JOL group exceeded the no-JOL group (46.33 vs. 36.77, respectively; *F*(1, 123) = 8.05, *MSE* = 1106.59, *η*p2 = .06). Additionally, this analysis yielded a significant effect of pair type was detected, *F*(2, 246) = 455.54, *MSE* = 138.13, *η*p2 = .79. Collapsed across encoding groups, correct cued-recall was greatest for forward associates (66.67), followed by mediated associates (34.02), and unrelated pairs (23.73). Follow-up testing indicated that all differences in cued-recall between pair types were significant, *t*s ≥ 3.66, *d*s ≥ 0.46.

Finally, a significant Encoding Group × Pair Type interaction emerged, *F*(2, 246) = 15.60, *MSE* = 138.13, *η*p2 = .11. Post-hoc testing confirmed the presence of a positive JOL reactivity effect on forward paired-associates, as mean cued-recall was greater for participants who provided JOLs at encoding relative to the No-JOL group (75.45 vs. 58.07, respectively; *t*(123) = 4.96, *SEM* = 3.61, *d* = 0.87). Importantly, this pattern extended to mediated paired-associates (39.19 vs. 29.01; *t*(123) = 2.48, *SEM* = 4.20, *d* = 0.44), replicating reactivity patterns observed on mediated pairs reported by Maxwell and Huff (2024). However, for unrelated pairs, cued-recall did not differ between the JOL and No-JOL groups (24.25 vs. 23.23; *t*(123) < 1, *SEM* = 3.80, *p* = .75, *p*BIC = .91).

**Experiment 1B**

Next, Experiment 1B tested whether positive reactivity reported on mediated paired-associates would extend to backward mediated paired-associates. Following the design of Experiment 1A, cued-recall was analyzed using a 2 (Encoding Group: JOL vs. No-JOL) 3 (Pair Type: Forward vs. Backward Mediated vs. Unrelated) mixed measures ANOVA. Overall, this analysis yielded a significant main effect of Encoding Group as, collapsed across Pair Types, cued-recall was greatest for participants in the JOL group compared to the No-JOL group (47.68 vs. 38.15; *F*(1, 113) = 10.29, *MSE* = 759.22, *η*p2 = .08). Next, a significant main effect of Pair Type was detected, *F*(2, 226) = 553.57, *MSE* = 121.79, *η*p2 = .83. Across encoding groups, cued-recall was highest for forward paired-associates (68.61), followed by backward mediated paired-associates (38.81), and unrelated pairs (20.96). Post-hoc testing confirmed that all comparisons significantly differed, *t*s ≥ 7.30, *d*s ≥ 0.96.

Importantly, this analysis revealed a significant Encoding Group × Pair Type interaction, *F*(2, 226) = 32.11, *MSE* = 121.79, *η*p2 = .22. Starting with forward paired-associates, a strong positive reactivity effect occurred, as recall for this pair type was greater in the JOL versus No-JOL group (78.99 vs. 58.76; *t*(113) = 5.85, *SEM* = 3.49, *d* = 1.09). Critically, this positive reactivity pattern also extended to recall of backward mediated paired-associates (44.58 vs. 33.33; *t*(113) = 2.99, *SEM* = 3.80, *d* = 0.56). However, no cued-recall differences were detected between the JOL and No-JOL groups for unrelated pairs (19.46 vs. 22.37; *t*(113) < 1, *SEM* = 3.00, *p* = .33, *p*BIC = .87). Thus, like the Experiment 1A, JOLs were reactive on cued-recall, but only when pairs contained pre-existing cue-target relations.

**Discussion**

The previous set of experiments assessed whether JOL reactivity patterns previously reported with mediated paired-associates would replicate (Experiment 1A) and whether these patterns would extend to backward mediated associates, which flipped the order in which the cue and target were paired (Experiment 1B). In doing so, Experiments1A/1B provided additional tests of the cue-strengthening and relational encoding accounts of JOL reactivity, which make diverging predictions regarding JOL reactivity on mediated paired-associates. Consistent with previous JOL reactivity studies (e.g., Maxwell & Huff, 2022; Soderstrom et al., 2015), the requirement to make JOLs at encoding improved memory for forward paired-associates compared to the no-JOL control group, but JOLs were non-reactive on unrelated pairs. Importantly, positive JOL reactivity was also observed on mediated paired-associates in Experiment 1A, replicating previous patterns reported by Maxwell and Huff (2024) and, additionally, this pattern also extended to backward mediated associates in Experiment 1B.

Because both types of mediated associates lack obvious relatedness cues which participants can use to inform their JOLs, findings in Experiments 1A/1B are consistent with a relational encoding account of JOL reactivity rather than a cue-strengthening account. However, even though both mediated pair types lacked a priori relatedness based on free-association norms (i.e., the Forward Associative Strength (FAS) between cue and target for all pairs was 0), these pairs may still have been perceived as having some degree of relatedness. Consistent with this account, mean JOLs for mediated pair types in both experiments exceeded JOLs for unrelated pairs (Experiment 1A: 40.70 vs. 28.55, respectively; Experiment 1B: 38.50 vs. 23.29; *t*s ≥ 9.29, *d*s ≥ 0.72). While the magnitude of JOLs can be influenced by a myriad of factors, including processing fluency and participants’ beliefs about stimuli, perceived relatedness between items is a highly salient cue for later remembering (see Koriat, 1997). Moreover, JOLs may have been inflated if participants were able to successfully guess a pair’s mediator, which likewise would have facilitated cued-recall.

Therefore, the goal of Experiments 2A/2B was to provide a stronger test of the relational encoding account of JOL reactivity by using double-mediated paired-associates. Based on a spreading activation account, any relational encoding from JOLs would be less likely to strengthen pre-existing cue-target relations relative to one-step mediated pairs, given the increased distance between cue and target in the associative network. Moreover, the increased distance between concepts would also make inadvertent guessing of intermediary items less likely. However, if JOL reactivity reflects the JOL strengthening pre-existing cue-target relations, then JOLs would be expected to be reactive on double-mediated pairs. As such, Experiments 2A/2B sought to provide a stronger test of the relational encoding account of JOL reactivity by testing whether reactivity patterns reported on mediated/backward mediated paired-associates in Experiments 1A/1B would extend to this pair type.

**Experiment 2A: Double-Mediated Paired-Associates**

Findings from the previous set of experiments are consistent with a relational encoding account of JOL reactivity and suggest that positive JOL reactivity on cue-target word pairs reflects the JOL task strengthening underlying relations between cue and target. However, as noted above, participants JOLs were often greater for mediated paired-associates compared to unrelated pairs, suggesting that participants may have still perceived mediated pairs as being thematically related even though the cue and target were unrelated based on free-association norms. Moreover, because JOLs are thought to direct participants’ attention towards intrinsic relatedness cues which inform their JOLs (e.g., Koriat, 1997), the act of making JOLs may have encouraged participants to guess the mediator.

To account for this possibility, Experiment 2A used double-mediated paired-associates. Unlike mediated pairs utilized in the previous set of experiments in which the cue and target are linked by a single concept, words presented in double-mediated pairs are connected through two, linked concepts. Importantly, although the target in a double-mediated pair is a direct associate of the second mediator, it is unrelated to the first mediator or cue. To illustrate the double-mediated pair *school* – *sign* has a full associative pathway of *school* – *bus* – *stop* – *sign*. The FAS between *stop* and *sign* equals .112 based on the Nelson et al., free association norms; however, all other pairings of these concepts are unrelated based on the norms. Thus, double-mediated paired-associates provide a stimuli type in which guessing the potential links between paired items is more difficult. Additionally, the greater distance between cue and target in the associative network also provides a stronger test of the relational encoding account of JOL reactivity, as any activation of the target word through spreading activation would be expected to be weaker relative to when concepts are mediated by a single concept (e.g., *school* – *stop*).

**Method**

**Participants**

One-hundred-eighteen undergraduate students were simultaneously recruited from the University of Southern Mississippi (*n* = 66) and Midwestern State University (*n* = 52) and participated in Experiment 2A online for partial course credit. Like the previous set of experiments, all participants were randomly assigned to either JOL or no-JOL encoding groups. Data screening used the same criteria outlined in Experiment 1A, and this process removed five participants from the final sample, leading to responses from 113 participants being included in the following analyses (*n* JOL = 57; *n* no-JOL = 56). A sensitivity analyses conducted using *G\*Power 3.1* suggested that this final sample size was adequate to detect small main effects/interactions (*d* = 0.24, *α* = .05, 1 – *β* = .80).

**Materials and Procedure**

Experiment 2A used the same materials as the previous set of experiments with the following modification. All mediated paired-associates were replaced with double-mediated paired-associates, in which the cue and target were indirectly linked through two concepts. These pairs were created by taking the mediated associates in used in Experiment 1A and replacing each target with the target’s strongest forward associate (assessed via FAS; Nelson et al., 2004) that was not also a direct associate of the cue the cue or the first mediator (e.g., the mediated pair *beach* – *box*, becomes *beach* – *square*. In this example the associative path is *beach* – *sand* – *box* – *square*, *sand* and *box* are mediators, and the new target *square* is not a direct associate of either *beach* or *sand*). Thus, like the mediated pairs used in Experiments 1A/1B, items in double-mediated pairs do not share a direct relation but are indirectly related. All other aspects of Experiment 2A were consistent with the previous set of experiments, and Experiment 2A followed the same general procedure previously used in Experiments 1A/1B. This experiment took approximately 30 minutes to complete.

**Experiment 2B: Backward Double Mediated Associates**

[WORDS HERE]

**Method**

**Participants**

We recruited an additional 124 undergraduate students from Midwestern State University (*n* = 73) and the University of Southern Mississippi (*n* = 46). Recruitment occurred simultaneously across both testing sites, and all participants completed Experiment 2B online in exchange for partial course credit. Like the previous experiments, participants were randomly assigned to either the JOL or no-JOL encoding groups. Participants’ responses were screened using the same criteria as the previous experiments, and five participants were excluded from the following analyses. The final dataset contained responses from 119 participants (*n* JOL = 60; *n* no-JOL = 59). The initial sample size was modeled after the previous experiments, and a sensitivity analyses conducted with *G\*Power 3.1* suggested that our final sample was sufficient for detecting small main effects/interactions (*d* = 0.23, *α* = .05, 1 – *β* = .80).

**Materials and Procedure**

Experiment 2B followed the same general procedure outlined in the previous experiments and used the same materials as Experiment 2A with the following change. All double-mediated paired-associates were transformed into backward double-mediated paired-associates by flipping the order in which the cue and target were presented (i.e., the double-mediated pair *beach* – *square* becomes *square* – *beach*). In doing so, this produced a pair type in which the cue and target were still indirectly linked via two mediators. However, unlike the double-mediated pairs utilized in Experiment 2A, all first mediators were low FAS responses to the cue, and all second mediators were low FAS responses to the first. As such, this resulted in a pair type in which pairs were indirectly related through Backward Associative Strength (BAS) rather than FAS. Because BAS is often a poor marker for cued-recall (see Koriat & Bjork, 2005), this resulted in a pair type in which unrelated items were indirectly linked, but the links between concepts were poor predictors of later memory.

**Results: Experiments 2A and 2B**

Comparisons of cued-recall between the JOL and no-JOL groups are reported in Figure 2. Cued-recall scoring followed the same method as Experiments 1A/1B, which corrected for misspellings and grammatical errors. For completeness, all comparisons are reported in Appendix Table AX.

**Experiment 2A**

Like the previous experiments, we tested for changes in cued-recall between encoding groups and pair types using a 2 (Encoding Group: JOL vs. No-JOL) × 3 (Pair Type: Forward vs. Double Mediated vs. Unrelated) mixed measures ANOVA. This analysis revealed a significant main effect of Encoding Group, *F*(1, 111) = 22.70, *MSE* = 600.11, *η*p2 = .17. Across Pair Types, cued-recall rates were higher in the JOL group versus the No-JOL group (44.48 vs. 31.81). Additionally, a significant Pair Type main effect emerged, *F*(2, 222) = 767.13, *MSE* = 99.21, *η*p2 = .87. Consistent with Experiments 1A/1B, cued-recall rates were greatest for forward paired-associates (67.79), followed by mediated (27.70), and unrelated pairs (19.12), and follow-up *t*-tests showed that all comparisons were statistically significant, *t*s ≥ 3.80, *d*s ≥ 0.51.

Moreover, a significant Encoding Group × Pair Type interaction was detected, *F*(2, 222) = 13.69, *MSE* = 99.21, *η*p2 = .11, confirming that any potential reactivity patterns differed as a function of pair type. Overall, forward paired-associates demonstrated a robust positive reactivity pattern, as cued-recall was greater for the JOL group compared to the No-JOL group (77.25 vs. 58.15; *t*(111) = 6.15, *SEM* = 3.14, *d* = 1.16). Importantly, this positive reactivity pattern also extended to double mediated paired-associates (34.44 vs. 20.83; *t*(111) = 4.14, *SEM* = 3.32, *d* = 0.78). However, this pattern did not extend to unrelated pairs. Instead, cued-recall of unrelated pairs was numerically greater for JOL participants (21.75 vs. 16.42), but this difference did not reach statistical significance; *t*(111) = 1.90, *SEM* = 2.83, *p* = .06, *p*BIC = .63. Thus, like the previous set of experiments, JOLs were reactive on cued-recall, but only when pairs contained pre-existing cue-target relations.

**Experiment 2B**

Next, Experiment 2B tested whether positive reactivity patterns observed on double mediated associates would occur when these pairs were presented in the backward direction. Following the design of the previous experiments, we tested for reactivity using a 2 (Encoding Group: JOL vs. No-JOL) × 3 (Pair Type: Forward vs. Backward Double Mediated vs. Unrelated) mixed measures ANOVA. Overall, this analysis yielded a significant main effect of Encoding Group, such that collapsed across pair types, cued-recall was greater for participants in the JOL group relative to the No-JOL group (43.17 vs. 35.61, *F*(1, 117) = 6.52, *MSE* = 781.21, *η*p2 = .06). This model also indicated a significant main Pair Type main effect, *F*(1, 117) = 562.81, *MSE* = 113.22, *η*p2 = .82. Collapsed across Encoding Groups, cued-recall was greatest for forward associates (65.69), followed by backward double-mediated associates (30.70) and unrelated pairs (21.88). A set of post-hoc *t*-tests confirmed that all comparisons differed significantly, *t*s ≥ 3.62, *d*s ≥ 0.47.

Additionally, this analysis revealed a significant Encoding Group × Pair Type interaction, *F*(1, 117) = 13.88, *MSE* = 113.22, *η*p2 = .11. Following the design of the previous experiments, a set of post-hoc *t*-tests revealed that cued-recall of forward paired-associates was greater for participants in the JOL group relative to the No-JOL group (73.17 vs. 58.10; *t*(117) = 4.69, *SEM* = 3.26, *d* = 0.85). This positive reactivity pattern extended to backward double-mediated associates (34.17 vs. 27.18), though the effect was marginally significant, *t*(117) = 1.94, *SEM* = 3.63, *p* = .05, *d* = 0.36. However, cued-recall did not differ between the JOL and No-JOL encoding groups when participants studied unrelated pairs (22.17 vs. 21.18 *t*(117) < 1, *SEM* = 3.28, *p* = .86, *p*BIC = .91). Taken together, JOLs were reactive on cued-recall but, like the previous experiments, this effect was moderated by the presence of direct or indirect cue-target relations.

**Discussion**

[WORDS HERE]

**General** **Discussion**

[WORDS HERE]

**Conclusion**

[WORDS HERE]

**Open Practices Statement**

[WORDS HERE]

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[FIG 1 – 1A/1B]

[FIG 2 – 2A/2B]

**Appendix**

Table A1

*Summary Statistics for Cue and Target Concreteness, Length, and Frequency as a function of pair type.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pair Type | Position | *M* Concreteness | *M* Length | *M* Frequency |
| Forward | Cue | 5.24 (0.92) | 5.20 (1.44) | 2.51 (0.59) |
|  | Target | 5.44 (0.95) | 5.03 (1.28) | 3.53 (0.63) |
| Mediated (Ex 1A) | Cue | 5.82 (0.87) | 4.97 (1.30) | 3.35 (0.54) |
|  | Target | 5.52 (0.95) | 5.03 (1.10) | 3.13 (0.58) |
| Mediated (Ex 1B) | Cue |  |  |  |
|  | Target |  |  |  |
| Mediated (Ex 2A) | Cue |  |  |  |
|  | Target |  |  |  |
| Mediated (Ex 2B) | Cue |  |  |  |
|  | Target |  |  |  |
| Unrelated | Cue | 4.97 (1.24) | 5.10 (1.56) | 3.22 (0.82) |
|  | Target | 5.16 (1.00) | 5.17 (1.58) | 3.05 (0.78) |

*Note*: Frequency ratings were derived from SUBLTEX (Brysbaert & New, 2009). Concreteness ratings were derived from the English Lexicon Project (Balota et al., 2007). Parentheses denote *SD*s. All values are collapsed across study lists. Mediated pairs in Experiment 1 were separated by one concept. Mediated pairs in Experiment 2 were separated by two concepts. “B” experiments flipped the order in which mediated items were paired. The full stimuli set has been made available at [OSF LINK].

Table A2

*Associative Strength Summary Statistics for Forward Associates in each Study List*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| List | *M* | *SD* | *Min.* | *Max.* |
| List 1 | 0.445 | 0.234 | 0.141 | 0.808 |
| List 2 | 0.448 | 0.211 | 0.101 | 0.808 |

*Note:* Cells reflect FAS (forward associative strength) values derived from the University of South Florida Free Association Norms (Nelson et al., 2004).

Table A3

[BIG RECALL SUMMARY TABLE]