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

Nicholas P. Maxwell1 & Mark J. Huff2

1Midwestern State University, 2The University of Southern Mississippi

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**Author Note**

Correspondence regarding this article can be addressed to Nicholas P. Maxwell, Department of Psychology, Midwestern State University, 3410 Taft Blvd, Wichita Falls, TX, 76308. Email: nicholas.maxwell@msutexas.edu. Study materials, data files, and analysis code have been made available at: https://osf.io/p8wme/

**Abstract**

Judgments of learning (JOLs) improve cued-recall of related but not unrelated word pairs. Recently, Maxwell and Huff (2024) demonstrated that JOLs also improve cued-recall of semantically mediated paired-associates (e.g., *beach* – *box*), which are directly unrelated via free association norms yet indirectly linked through a non-presented mediator (e.g., *sand*), suggesting that making JOLs specifically encourages individuals to process pre-existing relations at encoding. The present study provided a further test of this account. First, Experiment 1A replicated positive reactivity patterns reported by Maxwell and Huff on mediated paired-associates while Experiment 1B tested whether these patterns would still occur when the cue and target were reversed within mediated paired-associates (i.e., backward mediated-paired associates). Next, Experiments 2A/2B explored whether reactivity would occur when participants studied double-mediated paired-associates where cue and target were indirectly linked through two mediators, which increased the associative distance between cue and target. Across experiments, we found that JOLs consistently improved memory for all related pair types, regardless of whether pairs were direct associates or indirectly related through mediators. Importantly, positive reactivity emerged on all mediated pair types, regardless of direction or associative distance of the mediation. Our findings provide further evidence that positive reactivity on related pairs reflects a relational encoding process such that JOLs strengthen pre-existing relations between concepts.

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Judgments of learning (JOLs) provide useful insights about the learning process. JOL manipulations are easy to implement at encoding, and these judgments can be made for a variety of stimuli (e.g., faces; Hourihan, Benjamin, & Liu, 2012; educational text passages; Ariel, Karpicke, Witherby, & Tauber, 2021). However, while JOLs can be applied to a variety of study situations, researchers commonly have participants provide them while studying cue-target word pairs. Within this context, JOLs are often framed as the percentage likelihood that participants will correctly recall a pair’s target on a later memory test if cued by the first word (see Rhodes, 2016). JOLs have often been assumed to be neutral measures with little or no effect on memory. However, research over the past decade has consistently found that JOLs are *reactive* on learning, particularly when particpants provide them concurrently with or immediately following study of cue-target word pairs (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). Thus, making JOLs at encoding modifies participants’ cued-recall relative to a separate group of participants completing a no-JOL control task such as silent reading.

Studies investigating JOL reactivity have revealed a consistent pattern of memory changes on cued-recall of word pairs. When participants make JOLs for related word pairs (e.g., *mouse* – *cheese*), cued-recall is typically improved relative to a no-JOL control group (i.e., *positive reactivity*; Halamish & Undorf, 2023; Janes et al., 2018; Maxwell & Huff, 2022; Soderstrom et al., 2015). However, when participants provide JOLs for unrelated pairs (e.g., *dog* – *spoon*), JOLs are non-reactive or can even lead to memory costs (i.e., *negative reactivity*; but see Mitchum et al., 2016; who reported no reactivity on related pairs and negative reactivity on unrelated pairs). Thus, merely providing JOLs at encoding is sufficient to modify participants’ memory for cue-target word pairs, though this effect is strongly tied to the presence or absence of pre-existing relations between paired words.

Several theories have been proposed to explain why JOLs improve cued-recall of related cue-target word pairs and, moreover, why this memorial benefit does not extend to unrelated pairs. 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 judged pair, which provide useful indicators of future recall performance. Furthermore, these cues are often highly salient and are used by participants at encoding to inform the magnitude of their JOLs. By strengthening these cues, JOLs improve memory for studied items compared to a no-JOL control task like silent reading, so long as the method of testing is sensitive to the specific cues which were strengthened. Thus, for reactivity to occur, the cue-strengthening account 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 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 often focused on this account. Overall, findings from studies investigating JOL reactivity on cued-target word pairs largely support the cue-strengthening account (e.g., Janes et al., 2018; Maxwell & Huff, 2023) and, specifically, this account’s central claim that JOL reactivity requires a match between encoding-based cues and the method by which memory is assessed. Consistent with this account, 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, providing further evidence that JOL reactivity requires a match between strengthened cues and test format.

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 these cues provide highly salient markers of later remembering and thus are particularly 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 overshadows other intrinsic cues which may also inform their JOLs and likewise induce reactivity.

Given the link between cue-strengthening and relatedness cues, recent work has begun exploring the extent to which the processing of pre-existing cue-target relations contributes to positive reactivity on related word pairs. For example, Maxwell and Huff (2022) compared JOLs with several non-metacognitive judgment tasks which still emphasized pair relations 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) and frequency of co-occurrence judgments (Experiment 3). Importantly, JOL reactivity on related pairs also mirrored memory benefits from an explicit relational encoding task in which participants were directly instructed to relate all word pairs together at encoding (Experiment 4). To explain these findings, the authors proposed that JOLs specifically encourage participants to engage in relational encoding of cue-target word pairs. Accordingly, JOL reactivity would be expected to occur whenever the cue and target are related, producing a memory advantage for related but not unrelated pairs. This is because any relational encoding would likely emphasize the shared relations between concepts. Importantly, this relational encoding account is consistent with Soderstrom et al.’s (2015) cue-strengthening account and provides an explanation of the specific mechanism by which cue-strengthening may occur on related word pairs.

Findings from other recent studies investigating JOL reactivity with cue-target word pairs are similarly 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, a majority of their participants (68.7% in Experiment 1 and 80.4% in Experiment 2) indicated that perceived cue-target relations were the single strongest factor influencing the magnitude of 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. Considered alongside findings from Maxwell and Huff (2022), there is growing evidence that JOL reactivity on cue-target word pairs reflects the contributions of a relational process.

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

As noted above, there is increasing evidence that positive JOL reactivity on cue-target pairs reflects the contributions of a relational encoding process. 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. As such, a priori relatedness is thought to represent the extent to which a concept is linked to related concepts within an associative network and is best represented by free-association norms (e.g., De Deyne et al., 2019; Nelson, McEvoy, & Schrieber, 2004). A priori 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 changes in a posteriori associations, as pairs which are perceived as being strongly related typically receive higher JOLs relative to pairs perceived as being unrelated.

Importantly, a priori and a posteriori associations are not mutually exclusive, and related cue-target pairs may be high in one or both types of relatedness. Regarding JOL reactivity, the cue-strengthening account predicts that a posteriori relatedness 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 also contributes to positive JOL reactivity, as this account proposes that JOLs specifically strengthen the pre-existing, underlying relations between cue and target. Thus, the relational encoding and cue-strengthening accounts emphasize different aspects of relatedness as mechanism underlying JOL reactivity.

To test between the cue-strengthening and relational encoding accounts of reactivity, researchers can manipulate the type of relations between paired items. One method is to change the direction of the association. 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 a high probability response to the cue and thus contains a strong a priori relation, backward pairs’ targets are unrelated to the cue based on free-association norms. As such, backward paired-associates lack an a priori relation. However, thematically, these items are still perceived as being similar, and thus backward associates still 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; Maxwell & Huff, 2021). However, although a posteriori relatedness cues do not benefit recall of backward associates (i.e., backward paired-associates generally have low recall relative to forward paired-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, suggesting that the presence of a relation between the cue and target alone may be sufficient to trigger a memorial benefit.

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*). Thus, unlike traditional paired-associates (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 their non-presented mediators 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 (2024) 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 previous 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 extended to cued-recall of semantically mediated pair-associates cannot be fully explained by the cue-strengthening account and instead suggests that simply providing JOLs at encoding likely strengthens pre-existing cue-target relations in addition to strengthening perceptible relatedness cues. 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 still 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.

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 paired-associates (Experiment 1B). Backward mediated paired-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 cued-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, 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 and 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 paired-associates (e.g., *Horse* – *Wheel*), which were originally taken from Balota and Lorch (1986) and Jones (2010). Pairs were randomly assigned to one of 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: https://osf.io/p8wme/.

**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 with the cue on the left-hand side and the target on the right. Next, participants who had been randomly assigned to the JOL encoding group 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 their 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 the limit was reached, participants immediately began the cued-recall test. This test presented them 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**

Next, Experiment 1B 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 mediated paired-associates presented in the forward direction, backward mediated paired-associates also contain an indirect link between the cue and target. However, by reversing the order of items within pairs, 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, given that targets in backward pairs are low probability responses to cue items based on free-association norms (i.e., even though pairs are linked through Backward Associative Strength (BAS), they are not related through FAS). As a result, backward mediated paired-associates provide a stronger test of the relational encoding account, as per this account, reactivity would be expected to occur anytime items within cue-target pairs share a relation, regardless of the direction of the association.

Based on previous research, we again anticipated that positive reactivity would extend to forward paired-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 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 lists of cue-target word pairs presented in Experiment 1A with the following exception. The order of all mediated paired-associates (e.g., *lion* – *stripe*) was reversed, such that these paired-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 paired-associates and unrelated pairs. Experiment 1B followed the same general procedure outlined in 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 A3). 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. 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 (75.54 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, such that cued-recall of this pair type was greater in the JOL group relative to 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 memory 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 tested whether JOL reactivity patterns previously reported on cued-recall of mediated paired-associates (Maxwell & Huff, 2024) would replicate using a new sample (Experiment 1A) and whether these patterns would extend to backward mediated paired-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). Finally, this pattern also extended to backward mediated paired-associates in Experiment 1B, providing further evidence that making JOLs specifically encourages participants to process pre-existing relations between cue-target word pairs.

Because both types of mediated paired-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 direct, a priori relation 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 participants’ 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 and thus is likely to influence JOL magnitude (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, which are mediated through two concepts instead of one. Based on a relational account, JOLs would still be expected to improve memory for targets in double-mediated paired-associates, though any potential memory benefits would likely be smaller due to the increased distance between concepts in the associative network (i.e., spreading activation). Moreover, the increased distance between the cue and target would also make inadvertent guessing of intermediary items less likely. Overall, if JOL reactivity primarily reflects the JOL strengthening pre-existing cue-target relations, then JOLs would be expected to be reactive on double-mediated paired-associates. However, a cue-strengthening account predicts no reactivity on this pair type, given the lack of salient relatedness cues for this pair type (i.e., double-mediated paired-associates would also be low in a posteriori relatedness, as the cue and target should appear semantically unrelated at encoding). Therefore, 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 when paired items were mediated through two concepts.

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

Findings from Experiments 1A/1B 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 paired-associates as being thematically related even though the cue and target were directly 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 the mediated pairs used previously in which the cue and target were indirectly linked through a single concept, words presented in double-mediated pairs are indirectly 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 the cue. To illustrate, the double-mediated pair *school* – *sign* has a full associative pathway between the cue and target in which the association travels through *school* – *bus* – *stop* – *sign*. Based on the Nelson et al., free association norms, the FAS between *school* and *bus* is .071, *bus* and *stop* is .063, and *stop* and *sign* is .112. However, all other pairings between these concepts are unrelated based on the norms, including any potential pairings of the target with the first mediator or cue. 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 Paired-Associates**

Experiment 2B then provided an additional test of the relational account of JOL reactivity by testing whether JOLs would improve cued-recall of double-mediated paired-associates presented in the backward direction. We again expected that making JOLs would improve cued-recall of forward-paired associates but that JOLs would be non-reactive on unrelated pairs. Furthermore, based-on findings in Experiment 1B with single backward mediated pairs, we anticipated that JOL reactivity would extend to backward double-mediated pairs, given the indirect, underlying relation between cue and target. Thus our reactivity predictions were based on a relational encoding account of JOL reactivity. However, because backward paired-associates are generally more difficult for participants to recall relative to forward pairs, we also expected that any reactivity effects observed on this pair type would likely be smaller than when they were presented in the forward direction in Experiment 2A.

**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 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 for Experiments 2A and 2/B followed the same method outlined in Experiments 1A/1B, which corrected for misspellings and grammatical errors. For completeness, all comparisons are reported in Appendix Table A3.

**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. 16.43), 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 paired-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 paired-associates (65.69), followed by backward double-mediated paired-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.

Importantly, 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. 58.08; *t*(117) = 4.69, *SEM* = 3.26, *d* = 0.85). This positive reactivity pattern extended to cued-recall of backward double-mediated paired-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. 21.58 *t*(117) < 1, *SEM* = 3.28, *p* = .86, *p*BIC = .91). Taken together, JOLs were reactive on cued-recall but again, this effect was moderated by the presence of direct or indirect cue-target relations.

**Discussion**

Overall, findings from Experiments 2A/2B provide further support for a relational encoding account of JOL reactivity. Across experiments, we again replicated previous findings that making JOLs improves cued-recall of forward paired-associates and that this effect does not extend to unrelated pairs. Importantly, positive JOL reactivity patterns observed using mediated paired-associates in Experiments 1A/1B still occurred when the cue and target were mediated through two concepts rather than one. Finally, although mean JOLs for mediated paired-associates still exceeded JOLs for unrelated pairs (Experiment 2A: 32.53 vs. 26.94, respectively; Experiment 2B: 32.24 vs. 24.75; *t*s ≥ 6.27, *d*s ≥ 0.37), these effects were lower compared to those observed in Experiments 1A/1B. Thus, compared to the previous set of experiments, JOLs before for mediated pairs were reduced when participants studied double-mediated paired-associates, further suggesting that double-mediated pairs were perceived as less related compared to single-mediated pairs. However, the indirect relation inherent to mediated paired-associates likely also increased encoding fluency, leading to higher JOLs for all mediated pairs, regardless of whether the cue and target were mediated through one or two concepts. Considered alongside the previous set of experiments, Experiments 2A/2B provide increasing evidence that JOL reactivity on cue-target word pairs reflects JOLs specifically strengthening pre-existing cue-target relations.

**General** **Discussion**

The present study tested the cue-strengthening and relational encoding accounts of JOL reactivity on cue-target word pairs. Based on a cue-strengthening account, the act of making JOLs strengthens perceptible relatedness cues which participants use to inform their JOLs. Separately, the relational encoding account proposes that the act of making JOLs specifically strengthens pre-existing cue-target relations, as the act of making JOLs encourages participants to engage in relational encoding. Each account predicts that JOLs will improve memory for related but not unrelated cue target pairs. However, these accounts make diverging predictions about mediated paired-associates, which appear unrelated at encoding yet are still indirectly related through the non-presented mediator. Thus, mediated paired-associates provide a unique pair type in which pairs lack a posteriori relatedness cues which would be enhanced via cue-strengthening yet contain an indirect relation which could be enhanced through relational encoding.

We tested between these accounts by having participants in each experiment silently read or provide JOLs for three types of cue-target word pairs prior to completing a memory test: Related pairs presented in the forward direction, mediated paired-associates in which the cue and target were not directly related via free-association norms but were instead linked through a non-presented mediator, and unrelated pairs which were not directly related or indirectly linked through a mediator. Importantly, each experiment manipulated the direction of mediated paired-associates (e.g., forward or backward) or distance of the mediation (single or double), providing four separate tests of the relational encoding account’s central claim that JOL reactivity on cue-target word pairs simply requires the presence of a pre-existing relation between the cue and target, regardless of whether particpants can directly perceive this relationship at encoding.

Starting with Experiment 1A, we found that JOLs improved memory for both forward and mediated paired-associates but were non-reactive on unrelated pairs. Thus, all related pair types showed a memory advantage, regardless of whether they were directly related or indirectly related via non-presented mediators, directly replicating previous findings from Maxwell and Huff (2024). Experiment 1B then replicated these positive reactivity on forward paired-associates and demonstrated that positive reactivity also extended to backward mediated paired-associates in which the order of the cue and target were flipped. Next, Experiment 2A showed that positive reactivity patterns also extended to double-mediated paired-associates (i.e., the cue and target were sequentially mediated through two concepts), and Experiment 2B showed that this pattern held for backward double-mediated paired-associates. Taken together, our findings from this set of experiments provide further evidence that JOL reactivity on cue-target word pairs reflects a relational process, as whether JOLs improved memory for cue-target pairs was contingent upon pairs containing a pre-existing relation, regardless of whether the cue and target were directly or indirectly related.

Overall, our finding that JOLs improved memory for all mediated pair types is consistent with previous research investigating the specific mechanisms underlying JOL reactivity on related cue-target pairs. Recently, Maxwell and Huff (2024, Experiment 1) demonstrated that making JOLs improved cued-recall of forward and mediated paired-associates. Because the cue-strengthening account posits that JOL reactivity is based on the strengthening of intrinsic relatedness cues, this account cannot fully explain reactivity on mediated paired-associates, given their lack of both a posteriori relatedness (i.e., perceptible relatedness cues). To explain why JOLs improved memory for mediated paired-associates, the authors proposed that the act of making JOLs at encoding specifically encourages participants to process cue-target relations (i.e., relational encoding) and that reactivity on mediated paired-associates likely reflected JOLs strengthening pre-existing cue-target relations, rather than primarily strengthening discernable relatedness cues as per Soderstrom et al.’s (2015) cue-strengthening account. Thus, even though mediated paired-associates lack obvious relatedness cues, they still show a memory improvement compared to unrelated word pairs.

Our repeated finding that positive reactivity consistently extends to mediated paired associates is consistent with Maxwell and Huff’s (2024) findings and provides further evidence of a relational encoding account. As noted above, because mediated paired-associates lack obvious relatedness cues, any reactivity observed on this pair type cannot be fully explained in terms of cue-strengthening. This becomes increasingly apparent for double-mediated paired-associates as, by increasing the associative distance between the cue and target, participants are increasingly less likely to guess the mediator, and pairs are less likely to appear thematically related (e.g., *lion* – *stripes* vs. *lion* – *flag*). Thus, our findings that JOL reactivity extended to both double-mediated pair types in Experiments 2A and 2B provide strong evidence for a relational encoding account of JOL reactivity.

We propose that JOL reactivity on mediated paired-associates reflects spreading activation. Specifically, when participants are tasked with providing JOLs at encoding, the act of making their JOL encourages participants to process the underlying relations between the cue and target. When pairs contain obvious relatedness cues (e.g., forward paired-associates), any relational encoding from JOLs likely occurs alongside cue-strengthening processes. However, when pairs lack obvious relatedness cues, this relational encoding still benefits retrieval so long as the cue and target contain an indirect relation (e.g., mediated-paired associates). This is because activation of the cue and target likely also activates the non-presented mediator concepts in memory. The additional relational encoding afforded by JOLs thus also strengthens the activation of the mediators, which in turn facilitate cued-recall of the target.

This account is consistent with previous research on JOL reactivity which similarly suggests that JOLs specifically encourage participants to process pre-existing cue-target relations. For example, Maxwell and Huff (2022; 2023) compared demonstrated that JOLs also improve cued-recall of backward paired-associates which, unlike forward paired-associates, have intrinsic relatedness cues which are poor predictors of later memory ability (i.e., *card* *– credit* at encoding vs. *card – ?* at test; see Koriat & Bjork, 2005). Thus, relatedness cues for backward associates are unavailable at test, producing a situation in which strengthened relatedness cues are not aligned with the test. Moreover, Rivers et al. (2023) recently questioned participants about the specific strategies they used when forming their JOLs and found that participants primarily reported using cue-target relatedness rather than other cues which could also benefit recall (e.g., perceptual cues, familiarity, etc.). Considered alongside the present study, these findings reveal a consistent pattern in which JOLs improve cued-recall of related pair types, regardless of the nature of the relationship (e.g., associative direction, direct vs. mediated. etc.).

However, while the present study provides increasing evidence for a relational encoding account of JOL reactivity, we note that the cue-strengthening and relational encoding accounts are not mutually exclusive. For example, when participants study pairs which contain obvious relatedness cues, cue-strengthening likely takes precedence, as the presence of salient relatedness cues is a strong marker of later memory and thus strongly affects the magnitude of particpants’ JOLs (Koriat, 1997). However, relational encoding process likely also contribute to reactivity within this context, as the additional relational encoding afforded by JOLs also strengthens these pre-existing relations. Consistent with this account, Rivers, Dunlosky, Janes, Witherby, and Tauber (2023) recently explored whether JOLs were reactive when participants learned category-cue pairs which contain a strong semantic relation between cue and target (e.g., *a type of entertainer – clown*) and letter-cue pairs in which strong semantic relations are absent (e.g., *cl – clown*; see Bieman-Copland & Charness, 1994). Overall, JOLs improved memory for category pairs but were non-reactive on letter pairs when cued-recall testing was used. Taken together, JOL reactivity appears to reflect a combination of cue-strengthening and relational encoding processes, such that relational processing is emphasized when items are linked through a pre-existing relation.

Finally, to further explore the relational nature of JOL reactivity, future studies should assess whether JOL reactivity effects can extend to other associative tasks beyond cued-recall of paired-associates. For example, if JOL reactivity on cue-target word pairs reflects JOLs strengthening pre-existing cue-target associations, JOLs would also be expected to facilitate repetition priming of related but not unrelated word pairs. Moreover, assessing reactivity on mediated cue-target pairs within this context would provide greater confidence in whether JOL reactivity reflects spreading activation. Ultimately, however, more work is needed to fully explore the mechanisms underlying positive JOL reactivity on related word pairs while simultaneously seeking to disentangle the specific contributions of relational encoding and cue-strengthening.

**Conclusion**

Previous research has found increasing evidence that JOLs are reactive on cued-recall of paired-associates. Although several accounts have been proposed to explain this effect, the cue-strengthening account (Soderstrom et al., 2015) has gained prominence in the literature. However, this account does not explain positive reactivity observed on backward paired-associates or mediated paired-associates, as both of these pair types violate at least one of the cue-strengthening account’s requisites for reactivity to occur. Alternatively, the relational encoding account posits that reactivity also reflects JOLs strengthening pre-existing cue-target relations. We directly tested between these accounts using various types of mediated paired-associates, which lacked strong relatedness cues but were indirectly linked via a non-presented mediator. Across experiments, we found that JOLs consistently facilitated cued-recall of all related pair types, regardless of whether they were directly related or indirectly related through mediators. Importantly, these effects held even after manipulating the direction of the mediated relation (Experiments 1B and 2B) and when pairs were mediated through two concepts (Experiments 2A and 2B). Taken together, our findings provide further evidence that JOL reactivity reflects a relational encoding process, which likely occurs alongside cue-strengthening. As such, the present study adds to a growing body of research suggesting that JOLs improve cued-recall through relational encoding, rather than solely as a function of cue-strengthening.

**Data Availability Statement**

Study materials, data files, and *R* code used for analyses have been made available via OSF https://osf.io/p8wme/

**Compliance with Ethical Practices**

The reported studies were approved by the Institutional Review Boards at Midwestern State University (Protocol ##22101701) and the University of Southern Mississippi (protocol # IRB-19-429). All participants provided informed consent prior to participating in the experiments. The authors report no conflicts of interest.

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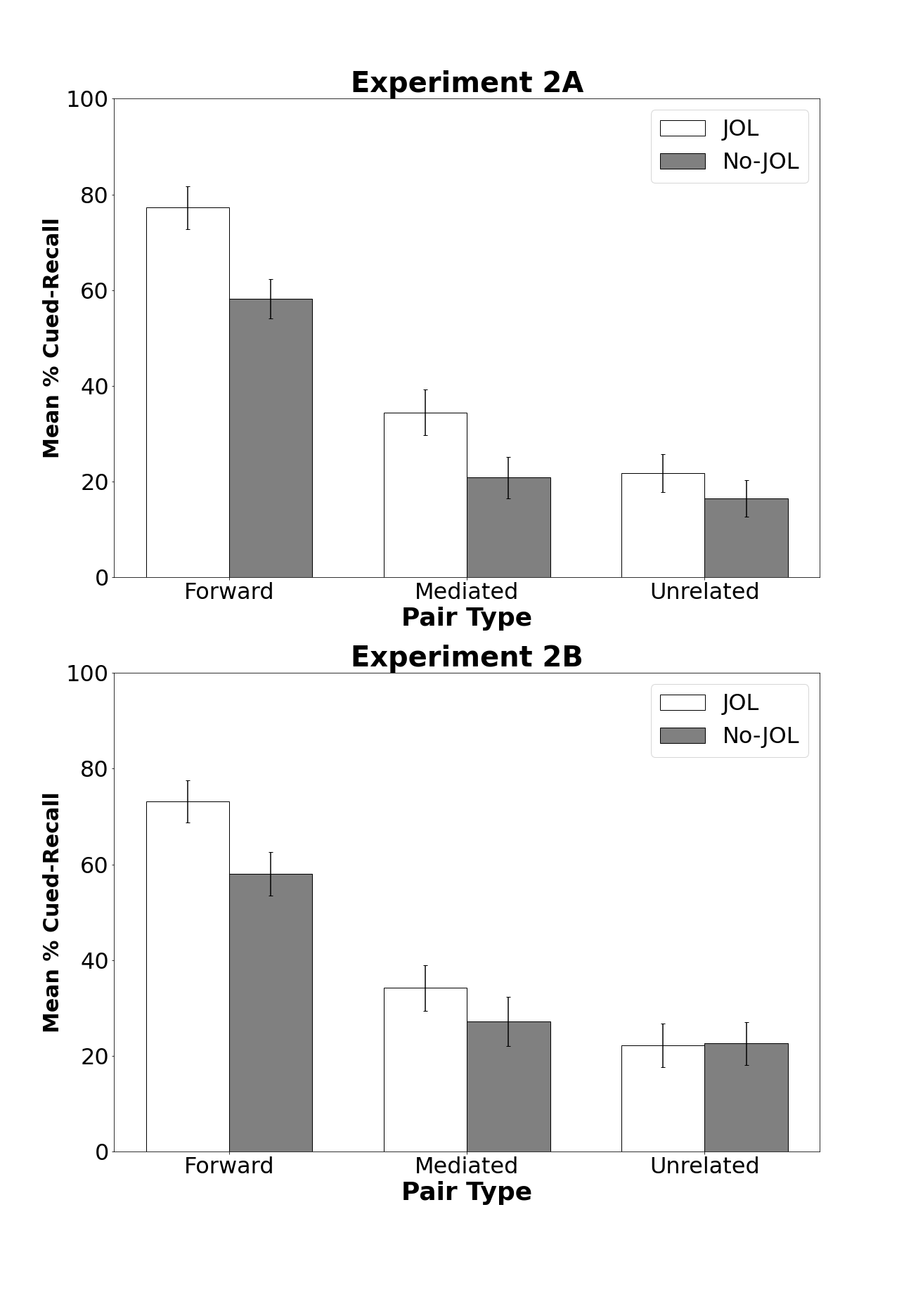
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A graph of different types of data

Description automatically generated with medium confidence

*Figure 1.* Comparison of mean cued-recall rates for all pair types in the JOL No-JOL groups in Experiments 1A (top panel) and 1B (bottom panel). Mediated pairs in Experiment 1B were presented in the backward direction. Bars = ± 95% *CI*s.



*Figure 2.* Comparison of mean cued-recall rates for all pair types in the JOL No-JOL groups in Experiments 2A (top panel) and 2B (bottom panel). All mediated pairs in Experiment 2 were mediated through two concepts, and mediated pairs in Experiment 2B were presented in the backward direction. Bars = ± 95% *CI*s.

**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 | 5.52 (0.95) | 5.03 (1.10) | 3.13 (0.58) |
|  | Target | 5.82 (0.87) | 4.97 (1.30) | 3.35 (0.54) |
| Mediated (Ex 2A) | Cue | 5.82 (0.87) | 4.97 (1.30) | 3.35 (0.54) |
|  | Target | 5.37 (0.95) | 4.37 (1.16) | 3.41 (0.64) |
| Mediated (Ex 2B) | Cue | 5.37 (0.95) | 4.37 (1.16) | 3.41 (0.64) |
|  | Target | 5.82 (0.87) | 4.97 (1.30) | 3.35 (0.54) |
| 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 mediated through two concepts. “B” experiments flipped the order in which mediated items were paired. The full stimuli set has been made available at: https://osf.io/p8wme/.

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

*Comparisons of Mean Recall Percentages for each Pair Type in Experiments 1A-2B.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Experiment | Encoding Group | Pair Type | *M* | ± 95% *CI* | F | M |
| Exp. 1A | JOL | Forward | 75.54 | 4.04 |  |  |
|  |  | Mediated | 39.19 | 6.05 | 1.76\* |  |
|  |  | Unrelated | 24.25 | 5.43 | 2.67\* | 0.65\* |
|  | No-JOL | Forward | 58.07 | 5.71 |  |  |
|  |  | Mediated | 29.01 | 5.47 | 1.33\* |  |
|  |  | Unrelated | 23.23 | 5.00 | 1.64\* | 0.27 |
| Exp. 1B | JOL | Forward | 78.99 | 3.96 |  |  |
|  |  | Mediated | 44.58 | 4.90 | 2.02\* |  |
|  |  | Unrelated | 19.46 | 3.39 | 2.40\* | 1.34\* |
|  | No-JOL | Forward | 58.76 | 5.42 |  |  |
|  |  | Mediated | 33.33 | 5.46 | 1.19\* |  |
|  |  | Unrelated | 22.37 | 4.67 | 1.84\* | 0.55\* |
| Exp. 2A | JOL | Forward | 77.25 | 4.48 |  |  |
|  |  | Mediated | 34.44 | 4.77 | 2.40\* |  |
|  |  | Unrelated | 21.75 | 3.96 | 3.41\* | 0.75\* |
|  | No-JOL | Forward | 58.15 | 4.11 |  |  |
|  |  | Mediated | 20.83 | 4.33 | 2.32\* |  |
|  |  | Unrelated | 16.43 | 3.79 | 2.76\* | 0.28 |
| Exp. 2B | JOL | Forward | 73.17 | 4.40 |  |  |
|  |  | Mediated | 34.17 | 4.82 | 2.14\* |  |
|  |  | Unrelated | 22.17 | 4.50 | 2.90\* | 0.65\* |
|  | No-JOL | Forward | 58.08 | 4.54 |  |  |
|  |  | Mediated | 27.18 | 5.15 | 1.62\* |  |
|  |  | Unrelated | 22.58 | 4.50 | 2.00\* | 0.24 |

*Note*: The two right-most columns indicate Cohen’s *d* effect sizes for post-hoc comparisons, \* = *p* < .05. F = forward paired-associates, M = mediated paired-associates. Mediated pairs in Experiment 1 were separated by one concept. Mediated pairs in Experiment 2 were mediated through two concepts. “B” experiments flipped the order in which mediated items were paired.