Judgments of Learning Facilitate Cued-Recall of Single and Double Semantically Mediated Word Pairs

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**Declarations**

**Ethics Approval:** The reported studies were approved by the University of Southern Mississippi Institutional Review Board (Protocol #IRB-19-429) and the Institutional Review Board at Midwestern State University (Protocol #22101701). Informed consent was obtained for all participants.

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**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 pairs (e.g., *beach* – *box*), which are directly unrelated via free association norms yet indirectly linked through a non-presented mediator (e.g., *sand*). Because mediated pairs lack perceptible relatedness cues, the finding that JOLs improve cued-recall of this pair type suggests that JOLs encourage individuals to process pre-existing relations at encoding. The present study further tests this account. Experiment 1A replicated positive reactivity patterns reported by Maxwell and Huff on mediated pairs while Experiment 1B tested whether these patterns would occur when the cue and target were reversed (i.e., backward mediated word pairs). Experiments 2A/2B explored whether reactivity would occur when participants studied double-mediated pairs where the cue and target were indirectly linked through two mediators, increasing the associative distance between items. Across experiments, JOLs consistently improved memory for both single and double mediated pair types in the forward and reversed directions. Finally, a cross-experimental meta-analysis revealed that JOLs produced robust reactivity on mediated and forward associates, though this effect was greatest for forward pairs. Taken together, our findings provide additional evidence that JOLs improve cued-recall by encouraging participants to process pre-existing relations between concepts.

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Judgments of Learning Facilitate Cued-Recall of Single and Double Semantically Mediated Word Pairs

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., educational text passages: Ariel, Karpicke, Witherby, & Tauber, 2021; human faces: Hourihan, Benjamin, & Liu, 2012). Although JOLs can be applied to many 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 participants 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, JOLs can modify cued-recall relative to control tasks like silent reading.

Studies investigating JOL reactivity have revealed a consistent pattern of memory changes on cued-recall of word pairs. When participants study related word pairs (e.g., *mouse* – *cheese*), JOLs often improve cued-recall relative to a control group (i.e., *positive reactivity*; Halamish & Undorf, 2023; Janes et al., 2018; Maxwell & Huff, 2022; Soderstrom et al., 2015; but see Mitchum et al., 2016; who reported no reactivity on related pairs). However, for unrelated pairs (e.g., *dog* – *spoon*), JOLs are either non-reactive (e.g., Maxwell & Huff, 2022; 2023; Soderstrom et al., 2015) or produce memory costs (i.e., *negative reactivity*; e.g., Undorf, Ingendahl, & Halamish, 2024). 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 word pairs and, moreover, why this benefit 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, two criteria must be met. First, JOLs must strengthen intrinsic cues about each judged pair, which are highly salient and provide useful indicators of future recall performance. Participants use these cues 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. Second, the cue-strengthening account also requires a match between strengthened intrinsic cues and test format. Therefore, the cue-strengthening account predicts positive reactivity whenever memory is assessed using a format that is sensitive to strengthened cues (e.g., relatedness cues and cued-recall testing).

Because the cue-strengthening account can explain the general reactivity patten observed for cue-target pairs (i.e., positive reactivity on related but not unrelated pairs), recent studies investigating the mechanisms behind JOL reactivity have often focused on this account. These studies have largely supported a cue-strengthening account (e.g., Janes et al., 2018; Maxwell & Huff, 2023) and, specifically, this account’s central claim that positive reactivity requires a match between encoding-based cues and test format. For example, Myers, Rhodes, and Hausman (2020) found that JOL reactivity patterns observed for cue-target pairs on cued-recall 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, further indicating that JOL reactivity requires a match between strengthened cues and test format.

Other studies have sought to identify the specific intrinsic cues which JOLs are purported to strengthen. Because prior work has often had participants study mixed lists of related and unrelated cue-target pairs, emphasis has been placed on the potential for JOLs to specifically strengthen relatedness cues, as these cues provide salient markers of later remembering and 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 cue-target relations likely overshadows other intrinsic cues which may also inform their JOLs and likewise induce reactivity.

Recent work has explored whether JOLs specifically strengthen cue-target relations. Maxwell and Huff (2022) compared JOLs to 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), which similarly emphasize cue-target relations. Moreover, JOL reactivity on related pairs also mirrored memory benefits found following an explicit relational encoding task which directly instructed participants to relate all word pairs together at study (Experiment 4). The authors proposed that while JOLs can potentially strengthen a variety of intrinsic cues, they specifically encourage participants to process pre-existing cue-target relations via *relational encoding*. Thus, JOLs should benefit memory whenever the cue and target are associated, given the emphasis on shared semantic relations. However, unrelated pairs would not be expected to show a memory improvement given they lack underlying relations. Importantly, this relational encoding account is complementary to Soderstrom et al.’s (2015) cue-strengthening account and provides greater specification regarding how cue-strengthening may occur on related pairs.

Findings from other studies also support the notion that JOLs specifically strengthen cue-target relations. For example, Rivers, Janes, Dunlosky, Witherby, and Tauber (2023) had participants complete a questionnaire following either silent reading or providing JOLs for related and unrelated cue-target word pairs and found that most of their participants (68.7% in Experiment 1 and 80.4% in Experiment 2) reported 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 versus unrelated pairs, cue-type judgments elicited at test were most accurate for related pairs, suggesting that JOLs are particularly sensitive to the presence of pre-existing cue-target relations.

Finally, Chang and Brainerd (2025) tested whether JOL reactivity was limited to semantic relations or if reactivity could occur for pairs with non-semantic relations (e.g., rhyme and homophone pairs). JOLs were non-reactive when pairs lacked a semantic relation, regardless of whether pairs contained phonological relations, though reactivity extended to mediated homophone pairs (e.g., *knight* – *evening*, which is mediated through the non-presented homophone *night*). To explain their findings, the authors proposed that JOLs facilitated elaborative processing (i.e., deep processing of semantic content; Craik & Lockhart, 1972). Per this account, elaborative processing may be either item-specific or relational in nature as semantic features can both connect and distinguish items (see Hunt & Einstein, 1981). Considered alongside other JOL reactivity studies, there is growing evidence that JOLs specifically encourage participants to process semantic relations relative to other intrinsic cue types.

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

There is increasing evidence that JOLs encourage relational encoding, particularly when they are provided for related cue-target pairs. However, the exact link between relational encoding and cue-strengthening remains unclear. As noted above, the cue-strengthening account requires a match between cues-strengthened at encoding and whether they are prioritized at test. Recent findings challenge this requirement, as positive reactivity has been observed for pair types in which relatedness cues are not diagnostic of later cued-recall (e.g., backward paired associates; Maxwell & Huff, 2023) and even when pairs are indirect associates that are unrelated through traditional free-association norms (e.g., mediated associates which appear unrelated at encoding; Maxwell & Huff, 2024). Critically, the finding that JOLs are reactive on mediated associates cannot be fully explained by cue-strengthening processes, given mediated pairs lack strong relatedness cues.

One explanation is that JOLs emphasize multiple aspects of word pair relatedness. For example, the relations between cue-target pairs can be classified as being *a priori* or *a posteriori* in nature (see Koriat, 1981). First, a priori relatedness represents the probability that a pair’s cue would elicit the target as a response. A priori relatedness is thought to reflect the extent to which concepts are linked within an associative network and are best represented by free-association norms (e.g., De Deyne, Navarro, Perfors, Brysbaert, & Storms, 2019; Nelson, McEvoy, & Schrieber, 2004). Because this type of relatedness can be directly measured via these free-association norms, we refer to this type of word pair relation as *normative relatedness*. Second, a posteriori relatedness reflects the judged degree of relatedness between the cue and target when both words are presented together at encoding. As such, it reflects participants’ in-the-moment perceptions of pair relatedness, irrespective of normed response probabilities (Koriat, 1981). We refer to this type of word pair relation as *perceived relatedness*.

Both normative and perceived relatedness can influence JOLs. For example, normative relatedness is critical for cued-recall testing, as pairs which are low in association strength have targets that are more difficult to retrieve at test. Any strengthened relatedness cues in a pair with low normative relatedness (e.g., backward paired-associates) would not be diagnostic of later remembering. However, JOLs are particularly sensitive to changes in perceived relatedness. For example, pairs which are perceived at encoding as being strongly related typically receive higher JOLs relative to pairs perceived as being unrelated, regardless of their underlying levels of normative relatedness. Importantly, normative and perceived relatedness are not mutually exclusive, as word pairs may be high in one or both types of relatedness (see Koriat & Bjork, 2005).

Regarding JOL reactivity, the cue-strengthening account predicts that normative relatedness primarily drives positive JOL reactivity on related cue-target pairs. This is because, per this account, reactivity will occur whenever the testing method is sensitive to cues strengthened at encoding. Because normative relatedness is diagnostic of later recall (i.e., pairs with strong pre-existing associations have targets that are high probability responses), strengthening these cues will facilitate cued-recall, provided the test is sensitive to these cues (i.e., cued-recall testing). However, relational encoding would also be expected to facilitate memory when pairs are high in perceived relatedness, even if perceived relations are not predictive of later remembering. If JOLs also encourage relational encoding of stimuli, they would be expected to strengthen the pre-existing, underlying relations between cue and target, including those which may not be fully captured in terms of free-association norms (i.e., backward pairs). Thus, whether reactivity primarily reflects cue-strengthening or relational encoding may partially depend upon the specific relations between the cue and target.

To test the extent to which relatedness influences reactivity, researchers can manipulate the relations between word pairs. One method is to alter the direction of pairs’ normed associative strength. For example, *backward pairs* can be generated by taking asymmetrical forward pairs (e.g., *text* – *book*) and simply flipping the cue and target’s order (e.g., *book* – *text*). Unlike forward pairs which have high probability targets and thus strong normative relatedness, backward pair targets are unrelated to the cue based on free-association norms, producing a pair type in which the target is not a common response to the cue. However, thematically, these items are still perceived as related at encoding, as backward pairs have strong perceived relatedness. For example, participants typically assign high JOLs to backward pairs (approximating those given to forward pairs), even though later cued-recall of forward pairs greatly exceeds backward pairs (i.e., *the illusion of competence*; see Koriat & Bjork, 2005; 2006; Maxwell & Huff, 2021). However, although perceived relatedness cues are less beneficial to cued-recall relative to normative relatedness (i.e., backward pairs generally have low recall relative to forward pairs), positive JOL reactivity still extends to this pair type (see Maxwell & Huff, 2022; 2023). Thus, reactivity still occurs even when relatedness cues are not diagnostic of later memory (i.e., there is a mismatch between strengthened cues and test format), suggesting that the presence of cue and target relations alone may be sufficient to trigger a memorial benefit.

The finding that positive reactivity readily extends to backward pairs suggests that JOLs can encourage participants to process underlying cue-target relations in addition to strengthening intrinsic cues. Recently, Maxwell and Huff (2024) tested this account by assessing whether positive JOL reactivity observed on related cue-target pairs extended to semantically mediated word pairs (e.g., *beach* – *box*), which appear unrelated at encoding (i.e., they lack both normative and perceived relatedness) but are indirectly related through a non-presented semantic mediator (e.g., *sand*). Unlike forward pairs (e.g., *beach* – *ball*), mediated pairs do not contain obvious relatedness cues. However, mediated pairs still contain an indirect relation through the non-presented mediator. Thus, by including mediated pairs, participants studied a pair type in which items contained an indirect normative relationship yet lacked perceived relatedness cues to inform the magnitude of their JOLs.

Because mediated pairs are designed to appear unrelated at encoding, the cue-strengthening account predicts no memory benefit for this pair type. This is because mediated pairs lack perceptible relatedness cues for JOLs to strengthen (i.e., mediated pairs appear unrelated at encoding, as they are indirectly linked via the non-presented mediator). However, if JOLs also encourage relational encoding in addition to cue-strengthening, memory should be improved for all related pair types, regardless of whether pairs contain strong perceived relatedness cues, as relational encoding would also be expected to strengthen indirect relations (e.g., mediated links between concepts). Consistent with this account, Maxwell and Huff (2024) found positive reactivity using mediated word pairs, 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 at least partially reflects a relational encoding process.

**The Present Study**

As noted above, findings from previous studies suggest that JOLs may specifically encourage processing of pre-existing cue-target relations and, importantly, that this effect can improve cued-recall for pairs which appear unrelated, so long as they share an underlying relation (e.g., mediated pairs). Critically, Maxwell and Huff’s (2024) finding that positive JOL reactivity patterns extended to cued-recall of semantically mediated word pairs cannot be fully explained by a cue-strengthening account, suggesting instead that JOLs may also encourage relational encoding. However, although the mediated pairs utilized by Maxwell and Huff were designed to appear unrelated at encoding, it is possible that participants were still aware of these pairs’ underlying relations, particularly if they were able to guess the mediator at encoding. The present study sought to account for this possibility while providing a stronger test for relational encoding processes on JOL reactivity.

We first sought to replicate Maxwell and Huff’s (2024) finding that JOLs are reactive on cued-recall of mediated pairs (Experiment 1A) while additionally testing whether JOLs would also facilitate cued-recall of backward mediated pairs (Experiment 1B). Backward mediated pairs were generated by reversing the order of mediated paired items (e.g., *lion* – *stripes* becomes *stripes* – *lion*). Importantly, our inclusion of backward mediated pairs in Experiment 1B allowed us to reduce potential effects of participants consciously 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 (e.g., Koriat & Bjork, 2005, Maxwell & Huff, 2021). We then tested whether positive JOL reactivity would extend to double-mediated word pairs (i.e., pairs mediated through two concepts; e.g., *lion* – *flag*, which is mediated through *lion* – *tiger* – *stripes* – *flag*; see Chwilla & Kolk, 2002). Like the single-mediated pairs used in Experiments 1A/1B, double-mediated pairs were similarly presented in the forward (Experiment 2A) and backward directions (Experiment 2B). Double-mediated pairs provided a stronger test of a relational encoding account of JOL reactivity, as the increased distance between cue and target made it less likely that participants would guess the mediators at encoding. Thus, by including multiple mediated pair types, the present study provided a more complete test of whether perceived relatedness cues are a requisite for JOLs to facilitate cued-recall of word pairs.

**Experiment 1A: Mediated Pairs**

Experiment 1A sought to replicate previous findings reported by Maxwell and Huff (2024) demonstrating that positive JOL reactivity patterns observed for related pairs extend to semantically mediated pairs in which the cue and target are indirectly related through a non-presented mediator (e.g., *lion* – *stripes*; mediated through *tiger*). Consistent with previous studies (e.g., Maxwell & Huff, 2022; Rivers et al., 2023; Soderstrom et al., 2015), we expected that JOLs would improve memory for related cue-target pairs relative to participants completing a silent reading control task. Additionally, we anticipated that JOLs would be non-reactive on cued-recall of unrelated pairs. However, because the cue-strengthening account requires a match between strengthened cues and test format, cue-strengthening alone would not be expected to improve memory for mediated pairs, as this pair type appears unrelated at encoding. If reactivity also reflects a relational encoding process, the presence of an indirect association, even when weak as in mediated pairs, should produce positive reactivity. Based on Maxwell and Huff’s (2024) findings, we anticipated that JOLs would facilitate cued-recall of mediated pairs, even though this pair type lacks a perceived relation. Thus, findings in Experiment 1A were expected to support a relational encoding account of JOL reactivity.

**Method**

**Participants**

One-hundred-thirty-five undergraduate students completed Experiment 1A online in exchange for partial course credit. Participants were simultaneously recruited from either the University of Southern Mississippi (*n* = 63) or Midwestern State University (*n* = 72). Recruitment was based on an a priori power analyses conducted with *G\*Power 3.1* (Faul, Erdfelder, Buchner, & Lang, 2009) which suggested that 74 participants would be required to detect small-to-medium main effects/interactions or larger (*d* = 0.30; *α* = .05, 1 – *β* = .80). However, following Maxwell and Huff (2024), participant recruitment was increased to account for additional variability due to our use of online testing. Participants were randomly assigned to either the JOL or no-JOL groups. We excluded 10 participants from the final dataset due to low recall rates (i.e., < 5% across all pair types), which suggested that participants did not adhere to task instructions or having recall rates > 95% across pair types (which implied cheating at test). Our final sample contained responses from 125 participants (*n* JOL group = 62; *n* no-JOL group = 63), which was consistent with 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 included 30 forward pairs derived from Nelson et al.’s (2004) free association norms (e.g., *Litter* – *Trash*), 30 unrelated pairs (e.g., *Maze* – *Phone*), and 30 semantically mediated pairs (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). Each study list contained 45 cue-target pairs. Lists were matched on SUBTLEX frequency (Brysbaert & New, 2009), concreteness, and length, and forward pairs in each list were matched on forward associative strength (FAS; see Tables A1, A2, and A3 in the Appendix for stimuli properties). Additionally, each study list began and ended with five 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 is 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*, 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 later. Participants were additionally informed that pairs would be presented with the cue on the left 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 judgements using a 0-100 scale, such that higher values denoted a greater probability of correctly retrieving the target at test. 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 notified of the upcoming memory test. After receiving the 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. Following the design of Maxwell and Huff (2024), encoding for both groups was self-paced, and participants pressed the ENTER key to advance to the next trial after providing their JOL.

After completing the first study list, participants began a distractor task in which they alphabetized the 50 US states. This task was timed for 2 min and was immediately followed by 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 lieu 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 groups took approximately 30 minutes to complete the experiment.

**Experiment 1B:** **Backward Mediated Pairs**

Next, Experiment 1B tested whether positive JOL reactivity observed on mediated pairs in Experiment 1A would extend to mediated pairs presented in the backward direction. Like forward mediated pairs, backward mediated pairs 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, as targets in backward pairs are low probability responses to cue items based on free-association norms (i.e., even though pairs are mediated through Backward Associative Strength (BAS), they are not related through FAS). As a result, backward mediated pairs provide a stronger test of relational encoding relative to forward mediated pairs, since relational encoding would be expected to produce reactivity whenever words are directly or indirectly related, regardless of the direction of the association.

Based on previous research, we again anticipated that positive reactivity would extend to forward pairs and that no reactivity would be observed on unrelated cue-target pairs. Additionally, our predictions for backward mediated pairs were the same as our predictions for mediated pairs in Experiment 1A. Specifically, we expected 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 based on Experiment 1A, and a sensitivity analysis conducted with *G\*Power 3.1* suggested that our final sample was sufficient to detect small main effects/interactions or larger (*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 pairs (e.g., *lion* – *stripes*) was reversed, such that these word pairs were mediated in the backward direction (e.g., *stripes* – *lion*). All other aspects of the stimuli used in Experiment 1B were identical to the previous experiment, including the use of forward 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). 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 comparisons include a supplemental Bayesian estimate of strength of evidence supporting the null hypothesis (Bayesian Information Criterion; *p*BIC; see Masson, 2011; Wagenmakers, 2007). This analysis compares models which assume a null effect and a significant effect and generates a probability estimate of the null hypotheses being retained.[[1]](#footnote-1) 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. For completeness, all cued-recall comparisons are reported in the Appendix (Table A4). Finally, analyses of encoding durations for encoding groups as a function of pair type are reported in the Supplemental Materials (https://osf.io/x5j2b).

**Experiment 1A**

To test for JOL reactivity patterns on cued-recall, the data were analyzed via a 2 (Encoding Group: JOL vs. No-JOL) × 3 (Pair Type: Forward vs. Mediated vs. Unrelated) mixed ANOVA. Overall, a significant effect of Encoding Group emerged. Collapsed across Pair Types, the mean percentage of 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, *p*BIC = .18). Additionally, this analysis yielded a significant effect of pair type, *F*(2, 246) = 455.54, *MSE* = 138.13, *η*p2 = .79, *p*BIC < .001, in which across encoding groups, correct cued-recall was greatest for forward pairs (66.67), followed by mediated pairs (34.02), and unrelated pairs (23.73). Follow-up testing indicated that all cued-recall differences between pair types were significant, *t*s ≥ 3.66, *d*s ≥ 0.46, *p*BICs < .001.

Finally, a significant Encoding Group × Pair Type interaction emerged, *F*(2, 246) = 15.60, *MSE* = 138.13, *η*p2 = .11, *p*BIC = .07. Post-hoc testing confirmed the presence of a positive JOL reactivity effect on forward pairs, 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, *p*BIC < .001). Importantly, this pattern extended to mediated pairs (39.19 vs. 29.01; *t*(123) = 2.48, *SEM* = 4.20, *d* = 0.44, *p*BIC = .35), replicating reactivity patterns observed on mediated pairs reported by Maxwell and Huff (2024). Cued-recall did not differ between the JOL and No-JOL groups for unrelated pairs (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 pairs would extend to backward mediated pairs. Following the design of Experiment 1A, the same ANOVA type was used. Overall, this analysis yielded a main effect of Encoding Group as, across Pair Types, cued-recall was greatest for the JOL versus No-JOL group (47.68 vs. 38.15; *F*(1, 113) = 10.29, *MSE* = 759.22, *η*p2 = .08, *p*BIC = .07). A main effect of Pair Type was detected, *F*(2, 226) = 553.57, *MSE* = 121.79, *η*p2 = .83, *p*BIC < .001, in which cued-recall was highest for forward pairs (68.61), followed by backward mediated pairs (38.81), and unrelated pairs (20.96). Post-hoc testing confirmed that all comparisons differed reliably, *t*s ≥ 7.30, *d*s ≥ 0.96, *p*BICs < .001.

Importantly, this analysis revealed a significant Encoding Group × Pair Type interaction, *F*(2, 226) = 32.11, *MSE* = 121.79, *η*p2 = .22, *p*BIC < .001. Starting with forward pairs, 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, *p*BIC < .001). Critically, this positive reactivity pattern extended to recall of backward mediated pairs (44.58 vs. 33.33; *t*(113) = 2.99, *SEM* = 3.80, *d* = 0.56, *p*BIC = .12). 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 Experiment 1A, JOLs improved cued-recall when pairs contained pre-existing cue-target relations.

**Discussion**

Experiments 1A/1B tested whether JOL reactivity patterns previously reported on cued-recall of mediated pairs (Maxwell & Huff, 2024) would replicate using a new sample (Experiment 1A) and whether these patterns would extend to backward mediated pairs, which reversed the cue-target order of mediated pairs (Experiment 1B). In doing so, each experiment tested whether JOL reactivity reflected a relational encoding process, given that mediated pairs lack strong, perceptible relatedness cues for JOLs to enhance via cue-strengthening. 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 pairs compared to the no-JOL control group, but JOLs were non-reactive on unrelated pairs. Importantly, positive JOL reactivity was also observed on mediated pairs in Experiment 1A, replicating previous patterns reported by Maxwell and Huff (2024). Moreover, this pattern extended to backward mediated pairs in Experiment 1B, providing further evidence that making JOLs encourage relational encoding which strengthens both direct and indirect relations between the cue and target.

Because both mediated pair types lack perceived relatedness cues which participants can use to inform their JOLs, findings in Experiments 1A/1B suggest that JOLs encourage participants to process the underlying relations between paired associates. However, even though both mediated pair types lacked direct normative relations based on free-association norms (i.e., FAS between cue and target for all mediated pairs was 0), these pairs may still have been perceived as having some degree of relatedness. Though not a direct measure of relatedness, mean JOL ratings for mediated pairs 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, *p*BICs ≤ .12; see Appendix Table A5). While the magnitude of participants’ JOLs can be influenced by many factors such as processing fluency and participant beliefs about stimuli, perceived relatedness between items is a highly salient cue for later remembering and strongly influences 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.

To determine whether participants viewed mediated pairs as unrelated at encoding, we conducted an additional norming study (*n* = 35) where a separate group of participants recruited from Prolific rated the relatedness of all single-mediated, forward, and unrelated pairs used in Experiment 1A. For each pair type, this group of participants completed a Judgment of Associative Memory task (JAM; Maki, 2007; Valentine & Buchanan, 2013), in which they rated the probability that a pair’s target would be the first response to the cue. Responses were framed as the number of individuals out of 100 who would respond to the cue with the paired target, with higher JAMs indicating a greater degree of perceived relatedness. Overall, forward pairs received the highest JAMs (71.71), followed by mediated pairs (19.70), and unrelated pairs (11.04). All comparisons significantly differed (*t*s ≥ 2.42, *d*s ≥ 0.57, *p*BICs ≤ .59), suggesting that participants could distinguish between mediated and unrelated pairs at encoding.

Given these concerns, Experiments 2A/2B sought to provide a stronger test of relational encoding by using double-mediated pairs. Unlike single-mediated pairs, double-mediated pairs are linked through two concepts instead of one. Based on a relational encoding account, JOLs would still be expected to improve memory for targets in double-mediated pairs, though positive reactivity effects would likely be smaller due to the increased distance between concepts in the associative network (i.e., spreading activation). Importantly, the increased distance between the cue and target would also make inadvertent guessing of intermediary items less likely to occur. As such, double-mediated pairs would appear unrelated at encoding. Any positive reactivity observed on double-mediated pairs, which does not extend to unrelated pairs, would be taken as evidence that JOLs facilitate processing of pre-existing relations. However, if JOL reactivity primarily reflects a traditional cue-strengthening process, double-mediated pairs would not be expected to show a memory advantage, given they lack perceptible relatedness cues for JOLs to strengthen (i.e., 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 pairs in Experiments 1A/1B would still occur when paired items were mediated through two concepts.

**Experiment 2A: Double-Mediated Pairs**

Findings from Experiments 1A/1B suggest that positive reactivity on cue-target pairs reflects JOLs specifically strengthening the underlying relations between cue and target. However, as noted above, participants’ JOLs were often greater for mediated pairs than unrelated pairs, suggesting that they may have still perceived mediated pairs 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 attention towards intrinsic relatedness cues which inform their JOLs (e.g., Koriat, 1997), providing JOLs may have encouraged participants to guess the mediator, even though participants received no instructions to do so.

To account for this possibility, Experiment 2A used double-mediated pairs. Unlike the mediated pairs used in Experiments 1A/1B, in which the cue and target were indirectly linked through a single concept, 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 both the first mediator and the cue word. To illustrate, the double-mediated pair *school* – *sign* has a full associative pathway between the cue and target in which the association travels sequentially through *school* – *bus* – *stop* – *sign*. Based on the Nelson et al. (2004) 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 of the target with the first mediator or the cue. Thus, double-mediated pairs provide a pair type in which guessing the potential links between paired items is more difficult relative to single-mediated pairs. Finally, the greater distance between cue and target in the associative network also provides a stronger test of the relational encoding processes, as any activation of the target word through spreading activation would be expected to be weaker relative to when words are linked through 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, participants were randomly assigned to either JOL or no-JOL encoding groups. The same data screening criteria from Experiment 1A were applied, which removed five participants from the final sample , leaving 113 participants available for analysis (*n* JOL group = 57; *n* no-JOL group = 56). A sensitivity analyses conducted using *G\*Power 3.1* suggested that this final sample size was adequate to detect small main effects/interactions or larger (*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 pairs were replaced with double-mediated pairs, 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 or the first mediator (e.g., the mediated pair *beach* – *box*, becomes *beach* – *square*. In this example the associative pathway is *beach* – *sand* – *box* – *square*. The words *sand* and *box* are mediators, and the new target *square* is not a direct associate of either *beach* or *sand*; i.e., the FAS between *beach* and *square* is 0). Thus, like the single-mediated pairs used in Experiments 1A/1B, items in double-mediated pairs do not share a direct relation but are indirectly related through associated mediators (see Table A3). All other aspects of Experiment 2A were consistent with the previous experiments, and Experiment 2A followed the same general procedure. The experiment took approximately 30 minutes to complete.

To determine whether participants would view double-mediated pairs as unrelated at encoding, we conducted an additional norming study (*n* = 39) in which a new group of participants recruited from Prolific provided JAMs for all double-mediated, forward, and unrelated pairs used in Experiment 2A. Overall, forward pairs received the highest JAMs (74.76), followed by double-mediated pairs (20.92), and unrelated pairs (16.94). Importantly, JAMs did not differ between double-mediated and unrelated pairs (*t* < 1, *p* = .30, *p*BIC = .82), suggesting that participants perceived double-mediated and unrelated pairs as being indistinguishable at encoding.

**Experiment 2B: Backward Double-Mediated Pairs**

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 pairs presented in the backward direction. We again expected that making JOLs would improve cued-recall of forward pairs but that JOLs would be non-reactive on unrelated pairs. Furthermore, based on our findings in Experiment 1B with backward single-mediated pairs, we anticipated that JOL reactivity would extend to backward double-mediated pairs, given the indirect, underlying relation between cue and target. Thus, we anticipated that JOLs would encourage relational encoding, which would facilitate cued-recall of all related pair types, regardless of whether they were directly or indirectly related. However, because backward pairs 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**

An additional 124 undergraduate students from Midwestern State University (*n* = 73) and the University of Southern Mississippi (*n* = 46) participated in Experiment 2B. Recruitment occurred simultaneously at both testing sites, and all participants completed the study online in exchange for partial course credit. Participants were again 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 119 participants (*n* JOL group = 60; *n* no-JOL group = 59). The initial sample size was modeled after the previous experiments, and a sensitivity analysis conducted with *G\*Power 3.1* suggested that our final sample was sufficient for detecting small main effects/interactions or larger (*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 pairs were transformed into backward double-mediated pairs by flipping the order in which the cue and target were presented (i.e., the double-mediated pair *beach* – *square* becomes *square* – *beach*). This produced a pair type in which the cue and target were still indirectly linked via two mediators. However, unlike the double-mediated pairs in Experiment 2A, all first mediators were low BAS responses to the cue, and all second mediators were low BAS responses to the first. 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), backward double-mediated pairs provide a situation in which the cue and target are indirectly linked through mediators but the mediating links are 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 A4.

**Experiment 2A**

Like the previous experiments, we compared cued-recall between encoding groups and pair types using the same ANOVA design reported in Experiments 1A/1B. This analysis revealed a significant main effect of Encoding Group, *F*(1, 111) = 22.70, *MSE* = 600.11, *η*p2 = .17, *p*BIC < .001, which indicated that cued-recall was 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, *p*BIC < .001. Consistent with Experiments 1A/1B, cued-recall rates were greatest for forward pairs (67.79), followed by mediated pairs (27.70), and unrelated pairs (19.12). Follow-up *t*-tests showed that all comparisons were statistically significant, *t*s ≥ 3.80, *d*s ≥ 0.51, *p*BICs < .001.

Moreover, a significant Encoding Group × Pair Type interaction was found, *F*(2, 222) = 13.69, *MSE* = 99.21, *η*p2 = .11, *p*BIC = .14, indicating that reactivity patterns differed as a function of pair type. Overall, forward pairs 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, *p*BIC < .001). Importantly, this positive reactivity pattern also extended to double-mediated pairs (34.44 vs. 20.83; *t*(111) = 4.14, *SEM* = 3.32, *d* = 0.78, *p*BIC = .003). However, this pattern did not extend to unrelated pairs in which the difference between JOL and No-JOL groups was not statistically reliable (21.75 vs. 16.43; *t*(111) = 1.90, *SEM* = 2.83, *p* = .06, *p*BIC = .63). Thus, like our previous 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 pairs would occur in the backward direction. The same ANOVA design was again used. Overall, an effect Encoding Group indicated that cued-recall was greater for participants in the JOL group than the No-JOL group (43.17 vs. 35.61, *F*(1, 117) = 6.52, *MSE* = 781.21, *η*p2 = .06, *p*BIC = .30). An effect of Pair Type was also found, *F*(1, 117) = 562.81, *MSE* = 113.22, *η*p2 = .82, *p*BIC < .001, in which cued-recall was greatest for forward pairs (65.69), followed by backward double-mediated pairs (30.70) and unrelated pairs (21.88). Post-hoc *t*-tests confirmed that all comparisons differed reliably, *t*s ≥ 3.62, *d*s ≥ 0.47, *p*BICs < .001.

Importantly, an Encoding Group × Pair Type interaction was found, *F*(1, 117) = 13.88, *MSE* = 113.22, *η*p2 = .11, *p*BIC = .13. Post-hoc *t*-tests revealed that cued-recall of forward pairs was greater for participants in the JOL group than the No-JOL group (73.17 vs. 58.08; *t*(117) = 4.69, *SEM* = 3.26, *d* = 0.85, *p*BIC < .001). This positive reactivity pattern extended to cued-recall of backward double-mediated pairs (34.17 vs. 27.18), though the effect was at the standard criterion for significance, *t*(117) = 1.94, *SEM* = 3.63, *p* = .05, *d* = 0.36, *p*BIC = .62. However, unrelated pair cued-recall did not differ between the JOL and No-JOL groups (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**

Findings from Experiments 2A/2B further suggest that JOLs encourage relational encoding. Across experiments, we again replicated previous findings that making JOLs improves cued-recall of forward pairs and that this effect does not extend to unrelated pairs. Importantly, the positive JOL reactivity patterns observed using mediated pairs in Experiments 1A/1B still occurred when the cue and target were mediated through two concepts rather than one. Finally, although mean JOLs for double-mediated pairs still exceeded JOLs for unrelated pairs (Experiment 2A: 32.56 vs. 26.99, respectively; Experiment 2B: 32.16 vs. 24.76; *t*s ≥ 6.27, *d*s ≥ 0.37, *p*BICs < .001), these effects were smaller compared to those observed in Experiments 1A/1B (see Table A4). Compared to the previous set of experiments, JOLs for mediated pairs were reduced when participants studied double-mediated pairs. This pattern is consistent with the JAM data we collected in Experiment 2A, which strongly suggests that participants perceived double-mediated pairs as being unrelated at encoding. However, the indirect relation between cue and target 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 experiments, Experiments 2A/2B provide increasing evidence that JOL reactivity on cue-target word pairs reflects JOLs specifically strengthening pre-existing cue-target relations.

**Cross-Experimental Meta-Analysis**

To estimate the overall JOL reactivity effect size for each pair type, we conducted a random-effects meta-analysis in *R* using the *metafor* package (Viechtbauer, 2010). Each experiment contributed one effect size per condition (Cohen’s *d*), which resulted in 12 total comparisons. We first tested for an overall JOL reactivity effect across all pairs before separately testing for JOL reactivity effects on each pair type (see Figure 3). Across pair types, JOLs produced a positive reactivity effect, yielding a moderate positive reactivity effect, pooled *d* = 0.53, 95% *CI*[0.28, 0.77]. A significant heterogeneity test, *Q*(11) = 56.072, *p* < .001, *I*2 = 80.63, indicated high heterogeneity of true effects (Cochran, 1954), confirming that differences in reactivity were influenced by pair types.

We then conducted a separate set of meta-analytic models which tested reactivity effects across pair types. These models revealed a strong reactivity effect on forward pairs, pooled *d* = 0.98, 95% *CI*[0.79, 1.18]; *Q*(3) = 1.89, *p* = .60, *I*2 = 0.00, a medium-sized reactivity effect on mediated pairs, pooled *d* = 0.53, 95% *CI*[0.34, 0.71]; *Q*(3) = 2.76, *p* = .43, *I*2 = 0.00, no JOL reactivity effect on unrelated pairs, pooled *d* = 0.06, 95% *CI*[-0.15, 0.27]; *Q*(3) = 4.02, *p* = .26, *I*2 = 23.71. Thus, consistent with a relational encoding account, reactivity was strongest when pairs contained both a direct normative relation and perceived relatedness cues, though the presence of an indirect, mediated relationship was sufficient to produce a moderate JOL reactivity effect.

**General** **Discussion**

The present study tested whether positive JOL reactivity on related cue-target pairs reflects a relational encoding process. Based on Soderstrom et al.’s (2015) cue-strengthening account, the act of making JOLs strengthens relatedness cues that participants use to inform their JOLs, which benefits memory provided these cues are strong predictors of later cued-recall (e.g., normative relatedness). However, if JOLs also encourage participants to process pre-existing pair relations, positive reactivity would also be expected to occur on pairs are indirectly linked (e.g., mediated pairs). We tested this possibility by having participants in each experiment silently read or provide JOLs for three types of cue-target word pairs before completing a memory test: Related pairs presented in the forward direction, mediated pairs 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 mediators. Importantly, each experiment manipulated the direction of mediated pairs (e.g., forward or backward) and distance of the mediation (single or double), providing four separate tests of whether JOLs would facilitate memory for pair types lacking obvious relatedness cues.

Starting with Experiment 1A, we found that JOLs improved cued-recall of both forward and mediated pairs 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 positive reactivity on forward pairs and demonstrated that positive reactivity also extended to backward mediated pairs in which the order of the cue and target were reversed. Next, Experiment 2A showed that positive reactivity patterns also extended to double-mediated pairs (i.e., the cue and target were sequentially mediated through two concepts), and Experiment 2B showed that this pattern held for backward double-mediated pairs. Taken together, our findings 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 pairs contained perceptible relatedness cues.

Finally, to clarify the overall impact of JOLs on cued-recall, we conducted a random-effects meta-analysis drawn from each pair-type comparison. Overall, this analysis yielded a moderate overall JOL reactivity effect across pair types. Separate meta-analytic models for each pair type revealed a robust JOL reactivity effect on forward associates, a moderate effect on mediated pairs (collapsed across mediation type), and no effect on unrelated pairs. Taken together, these patterns converge with our findings in each experiment and additionally suggest that the presence of indirect relations between cue-target pairs is sufficient to produce JOL reactivity, even in the absence of direct, normative relations.

Overall, our finding that JOLs improved memory for all mediated pair types is consistent with previous research investigating relatedness as a specific mechanism underlying JOL reactivity on related cue-target pairs. Recently, Maxwell and Huff (2024, Experiment 1) demonstrated that JOLs improved cued-recall of forward and mediated pairs. Because the cue-strengthening account requires a match between test format and strengthened cues, this account cannot fully explain reactivity observed on mediated pairs, given their lack of perceived relatedness cues. To explain why JOLs improved memory for mediated pairs, the authors proposed that the act of making JOLs at encoding also encourages participants to process cue-target relations (i.e., relational encoding). As such, reactivity on mediated pairs likely reflected this relational encoding process, rather than primarily occurring from strengthened intrinsic cues as per Soderstrom et al.’s (2015) cue-strengthening account. As a result, JOLs still produce a memory advantage for mediated pairs even though they lack perceived relatedness cues for JOLs to strengthen.

Additionally, our finding that positive reactivity consistently emerges on single-mediated and double-mediated pairs aligns with Maxwell and Huff’s (2024) findings and further suggests that JOLs also encourage participants to process pre-existing cue-target relations (i.e., normative relatedness). As noted above, because mediated pairs lack perceived 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 pairs 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 that JOLs encourage relational encoding, which benefits cued-recall.

We propose that JOL reactivity on mediated pairs reflects a spreading activation process (Collins & Loftus, 1975). 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 perceptible related cues (e.g., forward pairs), any relational encoding from JOLs likely occurs alongside cue-strengthening processes. However, when pairs lack these cues, this relational encoding still benefits retrieval so long as the cue and target contain an indirect relation (e.g., mediated pairs). 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 strengthens the activation of the mediators, which in turn facilitates 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) demonstrated that JOLs also improve cued-recall of backward pairs which, unlike forward pairs, have intrinsic relatedness cues that are poor predictors of later memory ability (i.e., *card* *– credit* at encoding vs. *card – ?* at test; see Koriat & Bjork, 2005). Relatedness cues for backward associates are poor predictors of later test performance, producing a situation in which strengthened relatedness cues are not aligned with the test. Additionally, Rivers et al. (2023) recently questioned participants about the specific strategies they used when forming their JOLs and found that participants primarily reported using perceived 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.).

Additionally, our finding that JOLs reactively improve cued-recall of mediated pairs is also consistent with recent work from Chang and Brainerd (2025) showing that JOLs affect semantic relations. As noted in the Introduction, the authors showed that while JOLs benefited cued-recall of related pairs, this effect was limited to semantic relations rather than other types of potential word relations (e.g., homophone relations). To explain this finding, the authors proposed that JOLs encourage elaboration, which can improve memory through increased item-specific or relational processing. While the present study was not specifically designed to test the role of elaboration as a potential mechanism of JOL reactivity, our findings provide additional evidence that the presence of a semantic relationship, regardless of whether it is direct or indirect, is sufficient to produce a JOL reactivity effect. Moreover, our findings are consistent Chang and Brainerd’s Experiment 3 results, as they showed that positive JOL reactivity extended to phonological-semantic mediators (e.g., *coarse* – *class*, which is mediated through the non-presented word *course*).

Increased elaboration may also have contributed to reactivity effects observed in the present study. As noted by an anonymous reviewer, single-mediated word pairs may inherently lend themselves to greater elaboration compared to double-mediated pairs, given the shorter associative distance between the cue and target. Consistent with this account, a cross-experimental analyses of control group participants found that single mediated pairs in Experiment 1A were recalled at a higher rate relative to double-mediated pairs in Experiment 2A (29.01 vs. 20.83, *t*(117) = 2.23, *SEM* = 3.66, *d* = 0.42, *p*BIC = .48), though no differences were detected with backward mediated pairs in Experiments 1B/2B (33.33 vs. 27.18; *t*(118) = 1.61, *SEM* = 3.87, *p* = .11; *p*BIC = .75). However, the present study did not directly assess participants’ study strategies or their attempts to guess mediators, relying instead on participants’ JOLs as a proxy. Future research may wish to further explore this account by informing participants of the types of pairs they will be exposed to (i.e., that some unrelated pairs are linked via mediators) or by directly assessing whether participants can guess a pair’s mediators. However, given that reactivity consistently extended to double-mediated pairs, it is unlikely that elaboration alone can fully explain reactivity within this context.

While the present study provides increasing evidence that JOL reactivity reflects processing of semantic relations, it is important to note that this account is not mutually exclusive with cue-strengthening. For example, when participants study pairs which contain obvious relatedness cues which are diagnostic of later recall, cue-strengthening may take precedence, as the presence of salient relatedness cues is a strong marker of later memory and strongly affects the magnitude of particpants’ JOLs (Koriat, 1997). However, relational encoding processes likely also contribute to reactivity within this context, as the additional relational encoding afforded by JOLs 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. Considered alongside the present study, there is growing evidence that semantic associations are a requisite for reactivity on cue-target pairs and that JOLs primarily strengthen these relational cues. JOL reactivity likely reflects a combination of cue-strengthening and relational encoding processes, such that relational processing is emphasized whenever semantic associations are present.

To further explore the relational nature of JOL reactivity, future studies should also assess whether reactivity extends to other associative tasks beyond cued-recall of pairs. 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. Finally, JOLs may be beneficial in applied settings, such as when individuals are required to understand the links between ideas rather than recalling specific facts. Ultimately, more work is needed to fully explore how JOLs facilitate encoding of semantic relations while also disentangling the specific contributions of relational encoding and cue-strengthening.

**Conclusion**

Previous research has shown that JOLs are reactive on cued-recall of related word pairs. Although several accounts have been proposed to explain this effect, the cue-strengthening account (Soderstrom et al., 2015) has gained prominence in the literature. Although this account readily explains reactivity patterns observed on forward pairs, it cannot account for positive reactivity observed on backward pairs or mediated pairs, as both pair types violate at least one of the cue-strengthening account’s requisites for reactivity to occur. However, if JOLs also facilitate relational encoding, JOLs should improve cued-recall any time the cue and target are directly or indirectly related. We assessed this possibility by having participants make JOLs for various types of mediated pairs, which lacked strong relatedness cues but were indirectly linked through a non-presented mediator. Across experiments, 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 for 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.

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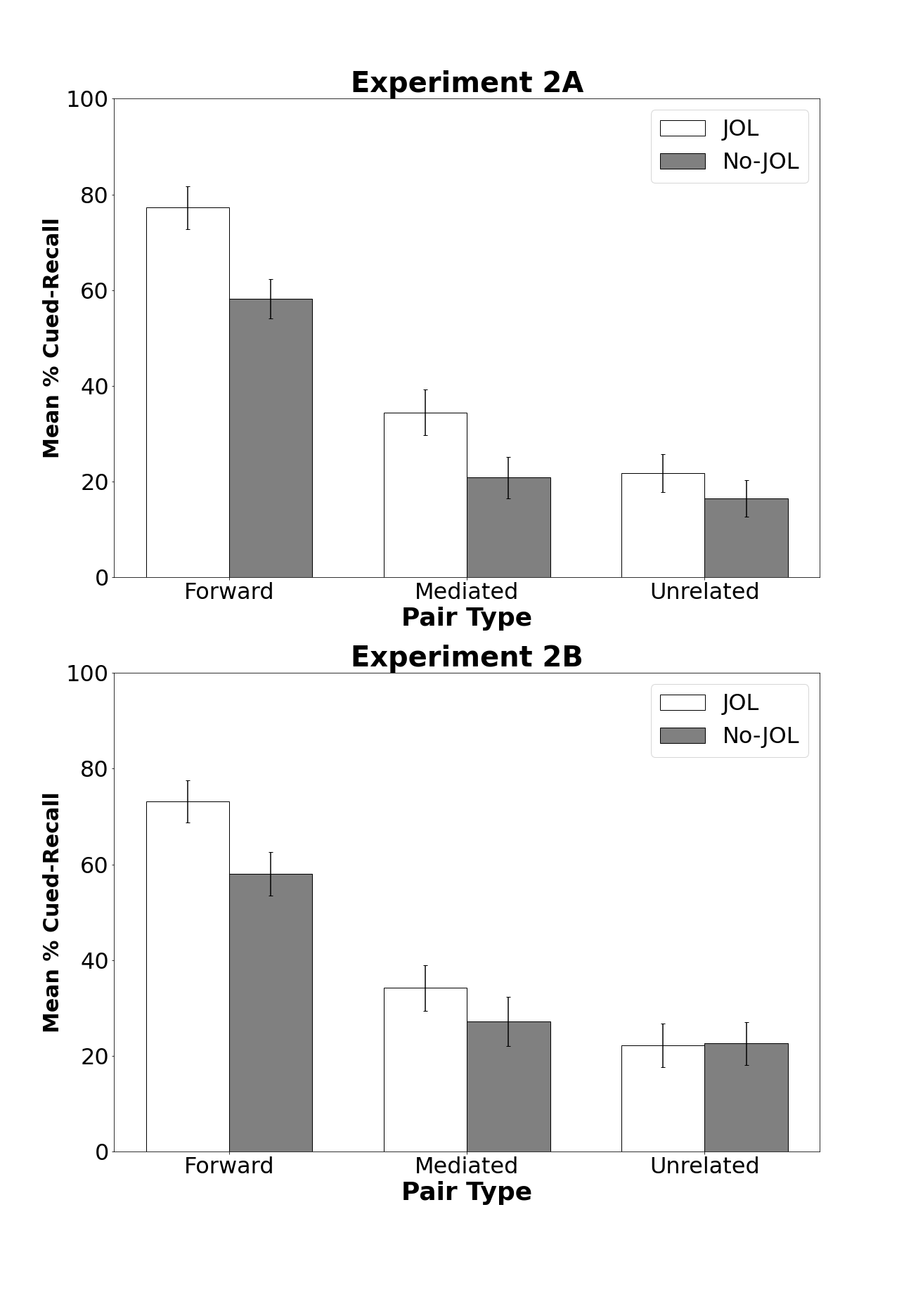
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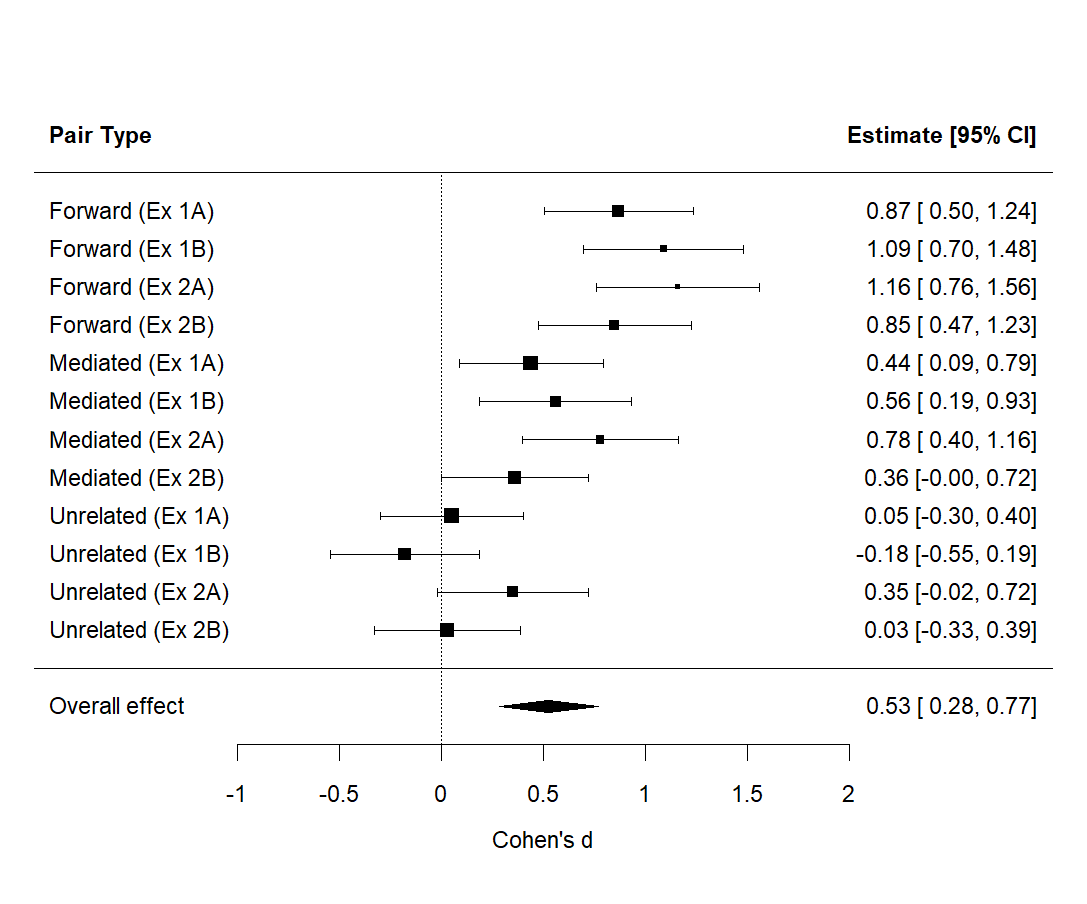
A graph of different types of data

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.



*Figure 3.* Forest plot displaying changes in Cohen’s *d* as function for each pair type in Experiments 1A-2B. Bars denote 95% *CI*s. Mediated pair types were mediated through one concept in Experiments 1A/1B and two concepts in Experiments 2A/2B. Mediated pairs in “A” experiments were presented in the forward direction. “B” experiments presented mediated pairs in the backward direction.

**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 linked through one concept. Mediated pairs in Experiment 2 were mediated through two concepts. “B” experiments flipped the order in which mediated words 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). The FAS between cue and target for all mediated and unrelated pair types was 0.

Table A3

*Associative Strength Summary Statistics for Single and Double-Mediated Associates in each Study List*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Experiment | List | Path | *M* | *SD* | *Min.* | *Max.* |
| Ex. 1A/1B | List 1 | Cue – Mediator | 0.29 | 0.23 | 0.00 | 0.82 |
|  |  | Mediator – Target | 0.11 | 0.13 | 0.00 | 0.36 |
|  |  | Cue – Target | 0.00 | 0.00 | 0.00 | 0.00 |
|  | List 2 | Cue – Mediator | 0.17 | 0.15 | 0.00 | 0.62 |
|  |  | Mediator – Target | 0.07 | 0.06 | 0.00 | 0.20 |
|  |  | Cue – Target | 0.00 | 0.00 | 0.00 | 0.00 |
| Ex. 2A/2B | List 1 | Cue – Mediator | 0.29 | 0.23 | 0.00 | 0.82 |
|  |  | Mediator – Mediator | 0.11 | 0.13 | 0.00 | 0.36 |
|  |  | Mediator – Target | 0.20 | 0.12 | 0.08 | 0.50 |
|  |  | Cue – Target | 0.00 | 0.00 | 0.00 | 0.00 |
|  | List 2 | Cue – Mediator | 0.17 | 0.15 | 0.00 | 0.62 |
|  |  | Mediator – Mediator | 0.07 | 0.06 | 0.00 | 0.20 |
|  |  | Mediator – Target | 0.22 | 0.13 | 0.09 | 0.52 |
|  |  | Cue – Target | 0.00 | 0.00 | 0.00 | 0.00 |

*Note:* Cells denote associative strength values taken the University of South Florida Free Association Norms (Nelson et al., 2004). “A” experiments presented pairs in the forward direction. “B” experiments presented pairs in the backward direction. Cue – Target path denotes strength of direct associative pathway without going through mediators.

Table A4

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Experiment | Encoding Group | Pair Type | *M* | ± 95% *CI* | F | M |
| Ex. 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 |
| Ex. 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\* |
| Ex. 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 |
| Ex. 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 pairs, M = mediated pairs. Mediated pairs in Experiment 1 were linked through one concept. Mediated pairs in Experiment 2 were mediated through two concepts. “B” experiments flipped the order in which mediated words were paired.

Table A5

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | Pair Type | *M* | ± 95% *CI* | F | M |
| Ex. 1A | Forward | 70.30 | 3.99 |  |  |
|  | Mediated | 40.70 | 4.01 | 1.86\* |  |
|  | Unrelated | 28.55 | 4.48 | 2.47\* | 0.72\* |
| Ex. 1B | Forward | 73.43 | 5.42 |  |  |
|  | Mediated | 38.50 | 5.46 | 2.02\* |  |
|  | Unrelated | 23.29 | 4.67 | 2.96\* | 0.97\* |
| Ex. 2A | Forward | 72.33 | 3.85 |  |  |
|  | Mediated | 32.56 | 4.09 | 2.60\* |  |
|  | Unrelated | 26.99 | 3.95 | 3.01\* | 0.37\* |
| Ex. 2B | Forward | 74.77 | 4.30 |  |  |
|  | Mediated | 32.16 | 4.81 | 2.36\* |  |
|  | Unrelated | 24.76 | 4.67 | 2.82\* | 0.40\* |

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

1. Note that *p*BICs lack cutoff values for interpretation and should not be interpreted as a replacement for *p*-values. Instead, *p*BICs estimate confidence in null effects, given their sensitivity to sample sizes. [↑](#footnote-ref-1)