Judgments of Learning Facilitate Relational Encoding: Evidence from One and Two-Step Semantically Mediated Paired-Associates

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**Author Note**

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**Abstract**

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

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

Because the cue-strengthening account explains the general reactivity that is often observed with cue-target pairs (i.e., positive reactivity on related pairs but no reactivity or negative reactivity on unrelated pairs), recent work has directly tested this account. Overall, findings from these studies largely support this account and, specifically, its claim that JOL reactivity requires a match between cues strengthened at encoding and the method by which memory is assessed. For example, Myers, Rhodes, and Hausman (2020) found that JOL reactivity patterns observed on cue-target pairs with cued-recall testing did not extend to free-recall in which cues were unavailable at test. This finding was later replicated by Chang and Brainerd (2023) who similarly found no memorial benefits of JOLs when free-recall testing was used. 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, these studies have often focused on the potential for JOLs to strengthen relatedness cues, since related pairs are often viewed by participants as more fluent and thus easier to encode (see Koriat & Bjork, 2005). Thus, although participants can potentially base their JOLs on a variety of intrinsic cues (e.g., concreteness, item-frequency, etc., see Dunlosky & Matvey, 2001), the presence of relatedness cues likely mitigates other intrinsic cues which could potentially contribute to reactivity. Additionally, cued-recall testing is particularly sensitive to relatedness cues (see XXXX).

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

Findings from other studies are similarly consistent with a relational encoding account of JOL reactivity. For example, Rivers, Janes, Dunlosky, Witherby, and Tauber (2023) had participants complete a questionnaire following either silently reading or providing JOLs for related and unrelated cue-target word pairs. Consistent with a relational encoding account of reactivity, a majority of their participants (68.7% in Experiment 1 and 80.4% in Experiment 2) indicated that perceived cue-target relations were the strongest factor influencing their JOLs. Seperately, 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. Taken together, it is likely that JOLs specifically emphasize relational processing of cue-target pairs.

Recently, Maxwell and Huff (2024) provided a further test of 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 but are indirectly related via a non-presented mediator (e.g., *sand*). Unlike traditional related pairs (e.g., beach – ball), mediated associates do not contain obvious relatedness cues. However, these items still contain pre-existing relations via the non-presented mediator. Thus, mediated paired-associates provide a scenario in which study items are related yet lack strong-relatedness cues. Based on a pure cue-strengthening account (e.g., Soderstrom et al., 2015), JOLs would not be expected to benefit memory for semantically mediated associates, as these pairs appear unrelated at encoding and thus lack discernable relatedness cues. However, if JOLs also encourage processing of pre-existing cue-target relations, the act of making JOLs should improve memory for all related pair types, even when these relations are not easily perceptible at encoding. Regarding mediated pairs, although these pairs lack strong relatedness cues, the non-presented mediator is likely activated at encoding through spreading activation (see Balota & Lorch, 1986; Jones, 2010). Thus, if JOLs also facilitate relational encoding, positive reactivity would be expected to occur on mediated associates. Consistent with this account, Maxwell and Huff (2024) found that positive reactivity on related associates readily extended to semantically mediated pairs, regardless of whether memory was assessed using cued-recall (Experiment 1) or recognition testing (Experiments 2 and 3). Considered alongside other studies assessing the link between relational encoding and cue-strengthening processes (e.g., Halmish & Undorf, 2023; Maxwell & Huff, 2022; Rivers et al., 2023), there is converging evidence that positive JOL reactivity on related pairs at least partially reflects JOLs facilitating processing of pre-existing cue-target relations.

**The Present Study**

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

Overall, we first sought to replicate Maxwell and Huff’s finding that JOLs are reactive on semantically mediated paired-associates (Experiment 1A) while also testing whether JOLs would similarly facilitate cued-recall of backward mediated associates (Experiment 1B), which were generated by switching the order of mediated paired items (e.g., *lion*-*stripes* becomes *stripes*-*lion*). By reversing the order of mediated-paired-associates, this allowed us to provide a stronger test of the relational account of JOL reactivity, as any potential relatedness cues which participants might derive from correctly guessing the mediator would be poor cues for later recall (see Koriat & Bjork, 2005, Maxwell & Huff, 2021, for reviews of backward paired-associates). Finally, we tested whether positive JOL reactivity would extend to two-step semantically mediated associates presented in the forward (Experiment 2A) and backward directions (Experiment 2B).

**Experiment 1A: Forward, Mediated, and Unrelated Cue-Target Pairs**

Experiment 1A sought to [OVERVIEW]

**Method**

**Participants**

We recruited 135 undergraduate students who completed Experiment 1 online in exchange for partial course credit. Participants were simultaneously recruited from two sources, with 63 recruited from the University of Southern Mississippi and the remaining 72 participants recruited from Midwestern State University. Recruitment was based on an a priori power analyses conducted with *G\*Power 3.1* (Faul, Erdfelder, Buchner, & Lang, 2009) which suggested that 74 particpants would be required to detect small-to-medium main effects/interactions (*d* = 0.30; *α* = .05, 1 – *β* = .80). However, following the design of Maxwell & Huff (2024), participant recruitment was increased to account for increased variability due to our use of online testing. Across recruitment sources, 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 consistent with Maxwell and Huff (2024). 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, Experiment 1). These pairs included 30 forward associates based on Nelson, McEvoy, and Schreiber’s (2004) free association norms (e.g., XXX-XXX), 30 unrelated cue-target pairs (e.g., XXX-XXX), and 30 semantically mediated associates (e.g., XXX-XXX) which were originally developed by Balota and Lorch (1986) and Jones (2010). Importantly, although mediated associates lacked a direct, a priori association based on Nelson et al.’s free association norms, they contained an indirect semantic mediator via the non-presented mediator (i.e., EXAMPLE; see XXXX). Pairs were then randomly split into two lists, with the constraint that each list contained 15 of each pair type (i.e., forward, unrelated, and mediated). As a result, 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., XXXX - ?).

**Procedure**

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

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

**Experiment 1B:** **Forward, Backward Mediated, and Unrelated Cue-Target Pairs**

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**Method**

**Participants**

An additional XX undergraduate students were recruited from the University of Southern Mississippi and completed Experiment 1B 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 utilized the same criteria outlined in Experiment 1A, and two participants were excluded from the final dataset. Our final sample contained responses from XX participants (*n* JOL = XX; *n* no-JOL = XX), and a sensitivity analyses conducted with *G\*Power 3.1* suggested that our final sample was sufficient to detect xx main effects/interactions (*α* = .05, 1 – *β* = .80).

**Materials and Procedure**

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

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

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

**Experiment 1A**

To test for JOL reactivity patterns on cued-recall, the data was analyzed via a 2 (Encoding Group: JOL vs. No-JOL) 3 (Pair Type: Forward vs. Mediated vs. Unrelated) mixed measures ANOVA. Overall, a significant main effect of Encoding Group emerged as, collapsed across Pair Types, mean correct cued-recall in the JOL group exceeded the no-JOL group (xx vs. xx, respectively; *F*(1, xxx) = xxx, *MSE* = xx, *η*p2 = .xx). Next, a significant effect of pair type was detected, *F*(2, xxx) = xxx, *MSE* = xx, *η*p2 = .xx, as correct recall was greatest for forward associates (xx), followed by mediated associates (xx), and unrelated pairs (xx). Follow-up testing indicated that all differences between pair types were significant, *t*s ≥ XX, *d*s ≥ 0.XX. Finally, a significant Encoding Group × Pair Type interaction emerged, *F*(2, xxx) = xxx, *MSE* = xx, *η*p2 = .xx. Post-hoc testing confirmed the presence of a positive JOL reactivity effect on forward paired-associates, as recall was greater for participants in the JOL group relative to the No-JOL group (xx vs. xx, respectively, *t*(xx) = xx, *SEM* = xx, *d* = xx). Importantly, this pattern extended to mediated paired associates (xx vs. xx, *t*(xx) = xx, *SEM* = xx, *d* = xx), 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 (xx vs. xx, *t*(118) = X, *SEM* = XX, *p* = .XX, *p*BIC = .xx.

**Experiment 1B**

[MODEL AFTER 1A]

**Discussion**

Experiments 1A and 1B tested [WORDS HERE]

**Experiment 2A: Two-Step Mediated Associates**

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