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schl5280@mylaurier.ca

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COMPARISON OF THE SENSITIVITY OF YES/NO AND FORCED CHOICE ASSOCIATIVE RECOGNITION

by

Garrett R. Schliewinsky

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Thesis

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Abstract

Yes-no (YN) and forced choice (FC) associative recognition tasks were compared across three experiments to test the varying effects of familiarity. Schliewinsky and Hockley (2016) previously found a discrimination advantage for FC tasks over YN tasks when word pairs were familiarized. The present research is a continuation to further explore the effects of increased familiarity. Experiment 1 manipulated the familiarity of individual items in the word pairs. No discrimination advantage for the FC condition over the YN condition was found when only item familiarity was increased, emphasizing the importance of associative information for accurate associative recognition. There was, though, a significant effect of item familiarity in the FC task but not for YN responses. Experiment 2 manipulated the familiarity of word pairs and compared simultaneous and sequential FC test procedures. Presentation format did not affect FC associative recognition performance. Due to shortcomings of Experiment 3, the significant discrimination advantage found for FC tasks over YN tasks was not replicated in a within-subjects design. Trends of the data suggest that this advantage does exist. This study provides evidence for reliance of familiarity-based recognition decisions in FC associative recognition tasks and recall-based recollection in YN associative recognition tasks. Researchers cannot assume models like signal detection theory can account for the equal sensitivity of FC and YN procedures for complex tasks such as associative recognition.

Keywords. Memory, associative recognition, familiarity, yes/no task, forced choice task.

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Comparison of the Sensitivity of Yes/No and Forced Choice Associative Recognition

Associative Recognition

Recognition memory is an individual’s ability to distinguish old and new stimuli. This is reliant on the ability to discriminate between previously presented stimuli and novel stimuli. Correct recognition of an old stimulus on a test contributes towards the participant’s hit rate. A false alarm is the incorrect memory judgement when identifying a novel stimulus as an old stimulus. The hit rates and false alarm rates of test items are the standard, raw measures for recognition memory tasks, and provide the basis for signal detection measures of discrimination such as *d’*.

Associative recognition is the ability to recognize stimuli based on their relations. Participants are provided a study list of paired items. At test, participants must discriminate between intact and rearranged pairs. Intact pairs are the items previously presented at study together and rearranged pairs contain the individual study items, but are paired with a different item. In order to correctly recognize an old pairing, participants must retrieve the relational information. Since both intact and rearranged test pairs consist of only old items, memory for the individual items cannot aid in the discrimination of old and new pairs. Thus, associative recognition provides a relatively pure test of memory of word pairs.

Mandler (1980) outlines that the dual-processing model of recognition memory relies on two types of processing; familiarity and recollection. Familiarity is the elicited sense or feeling of recognition when cued by a stimulus. This process is typically quick and less accurate than recollection. Recollection is the mental re-experiencing of the details of a memory or prior information. Recollection is a much slower, more detailed form of retrieval (see Jacoby & Whitehouse, 1989; Yonelinas, 2002).

Correct old responses in item and associative recognition can be based on familiarity, recollection, or a combination of both. False alarms, in turn, are based on the use of familiarity rather than recollection. In order to examine the influence of familiarity on item recognition, Greene (1999) presented half of the study items to participants in an initial familiarization list before the actual study list. This manipulation increased the familiarity of some of the words on the study list and led to an increase in both the hit and false alarm rates of the familiarized items compared to the non-familiarized items. This increase of both hits and false alarms is known as a concordant effect, which Greene (1999) states is the result of increased familiarity of the items. Increased familiarity does not always increase recognition accuracy. The concordant effect is in contrast to the mirror effect, which is the pattern of results that reflects more accurate memory, where the hit and false alarm rates are inversely related, creating a greater discrepancy between them (Glanzer & Adams, 1985).

Effects of Familiarity for Item and Associative Information

Several studies have investigated the effects of increased familiarity of word pairs, showing a relationship between item and associative information in recognition tasks. Cleary, Curran, and Greene (2001) tested for both associative and item recognition in separate experiments based on repeated pairs and plurality of words within the pairs. In the associative recognition experiment, individual words within the pairs were given in singular or plural forms at study. All pairs were presented again, but containing opposite singular and plural forms (e.g., *bulls-river*, *bull-rivers*). Each pair and their corresponding opposite pair were presented either once, 5 times, or 12 times on the study list. This would shift the focus from familiarity of the items to the plurality of the items. In the experiment testing for associative recognition, pairs were either presented intact with the same singular-plural pairings (e.g., *bulls-river*, *bull-rivers)* or rearranged with the opposing forms (e.g., *bulls-rivers, bull-river*) at test. At test, participants were asked to pay attention to the plurality of the words and to determine if the word pairs were presented as intact or rearranged. Participants made a frequency judgement by inputting the number of times they saw a particular word pair at study and were instructed to input a judgement of 0 if the pair was rearranged. In another experiment, they tested for item recognition. The procedure was similar, however, only one singular or plural form was presented in the pairs at study. At test, participants had to determine the frequency of how many times the word appeared and whether the word was the same or different in terms of plurality. Accuracy for repeated word pairs was improved for items in item recognition, but not for associative recognition (Cleary et al., 2001). Since both singular and plural forms of words were presented at study, item familiarity would not be useful for associative recognition. Thus, participants had to rely on recollection of the word pairs in order to make accurate responses. Repeating these word pairs at study increased the memory for the individual words and the plurality of words in each word pair more than improving memory of the associations for the specific pairings. Cleary et al. (2001) emphasized the different effects on item and associative information in both item and associative recognition tasks when word pairs are repeated. Since both forms of the words were presented at study, item recognition could not assist in accurate associative recognition. Only recollection of the associative information could result in accurate responding for associative recognition. Increased familiarity of the item information cannot assist in accurate performance in associative recognition tasks.

Kelley and Wixted (2001) repeated some word pairs at study several times (strong pairs) or once (weak pairs). This increased the familiarity strength of the items and the associations of the pairs. Repeated items and their associations increased the hit rates, but had no effect on false alarms compared to non-repeated pairs. Verde and Rotello (2004) also repeated study pairs either once (weak) or three times (strong) at study. In addition, the individual words within pairs were overlapped across pairs (e.g., A-B, A-C, D-B, D-C, etc.). Repeating pairs resulted in more accurate recognition of strengthened pairs. Across all pair types, the false alarm rate did not differ similar to Kelley and Wixted (2001). Their results indicated that repeating word pairs increases the hit rates without affecting the false alarm rates. Kelley and Wixted (2001) and Verde and Rotello (2004) argued that repeating word pairs increased the familiarity of the individual words and increased the familiarity of the associations. The increased strength of the associations then was responsible for the increased hit rates. Kelley and Wixted (2001) and Verde and Rotello (2004) both also argued that the increased familiarity of the items in the rearranged pairs was offset by the increased ability to recall-to-reject. This would explain the consistency of false alarm rates across repeated presentations. Where intact pairs are recognized based on the strength of the individual words and associations, recall-to-reject can assist in rejecting foils. The recall-to-reject process states that the individual items in a rearranged pair can be used to cue the recall of the original association, resulting in participants correctly rejecting the rearranged pairing (Rotello & Heit, 2000). Rotello and Heit (2000) had participants study a mixture of words and word pairs at study. When participants were tested on word pairs, rearranged pairs were rejected more than new unstudied pairs. Rotello and Heit (2000) attributed that the use of recall-to-reject was a result of the recalling the associative information. Recall-to-reject was used to counteract the increased familiarity of the rearranged pairs in Kelley and Wixted (2001) and Verde and Rotello (2004), explaining the lack of difference in false alarms.

Jou (2010) had participants study words presented in pairs one or three times. Participants were instructed to ignore the associations of the word pairs. This was an attempt to separate processing of item and associative information. Jou found that participants could not ignore the associative information based on the low pattern of responding to rearranged pairs and above chance associative recognition performance. Jou's main conclusion was that associative information interacts with and is influenced by item information. Both the item and associative information contribute to the overall familiarity of word pairs. Jou also concluded that item and associative information are difficult to separate from one another in associative recognition. Item information can influence associative recognition decisions even though item information is not the necessary information needed for accurate associative recognition responses.

Cohn and Moscovitch (2007) emphasized the importance of deep encoding of the associations of word pairings over the encoding of the item information for accurate associative memory. They found that associative identification (discriminating old and new word pairs based on familiarity) and associative reinstatement (recalling associative information) were dissociated from item information. Participants were given different encoding strategies based on shallow and deep encoding of the items and the associations. The *shallow item* condition had participants read each word aloud. The *deep item* condition had participants read the words aloud and rate each word on a five-point scale on concreteness and pleasantness. In the *deep association* condition, participants produced a sentence aloud containing the two words. Their results indicated that deeper encoding of associations resulted in more accurate associative recognition, and deeply encoded items did not increase accurate associative recognition, but did increase overall old responses. They concluded that associative memory may not entirely rely on recollection (associative reinstatement), as decisions for associative recognition also rely on the familiarity of the associations (associative identification) (Cohn & Moscovitch, 2007). Familiarity of the item and association information both influence the responding of participants in associative recognition. Increased familiarity of the items will increase both the hit rates and false alarm rates, and increased associative familiarity will increase the hit rates and accuracy.

Associative recognition tasks have also compared compound word (CW) to non-compound word pairs (NCW). CW pairs contain more semantic information than NCW pairs, unitizing the individual words, increasing their associative strength, which is responsible for accurate recognition (Quamme, Yonelinas, & Norman, 2007). For instance, the word pairing *water* and *fall* contain the semantic information of what a *waterfall* is based on previous knowledge. In contrast, the NCW pairing *wish* and *cabbage* has less unitization and no pre-experimental association.

Research on the fluency and the strength of these word pairs have been investigated. The more previous knowledge there is for a pairing, the more semantic memory that pair has. Experimentally based encoding of associations relates more to episodic memory. Several experiments have investigated different strategies for encoding of associations. Lloyd et al. (2015) gave definitions for the to-be-remembered random word pairs or used the words in word pairs in a sentence. For example, the word pairing *author-elbow* was accompanied by the definition “Joint pain caused by writing too much” or in the sentence “The *author* injured his *elbow* while swimming”. The definitions would encourage for more unitization of the word pairs and the sentences encouraged more binding of the pairs. Unitization fuses the two words into a whole, single concept, which supports greater use of familiarity in associative recognition (Lloyd et al., 2015).

Ahmad and Hockley (2014) compared associative recognition for CW pairs, which contained the pre-experimental unitization, with non-compound (NCW) word pairs constructed by rearranging the individual words or lexemes of compound words into random word pairings.

In the CW condition, participants had to discriminate between studied CW pairs (e.g, *check list*, *needle point*) and rearranged study compound words that also formed new compound word pairs (e.g., *check point*). Ahmad and Hockley found that both the hit rate and the false alarm rate were higher for CW pairs compared to NCW pairs, but there was no difference in discrimination in tests of yes-no associative recognition. They termed this concordant effect the “compound word effect”.

To further examine the compound word effect, Ahmad and Hockley (2017) manipulated the perceptual fluency of word pairs by presenting each word on separate screens at study and test. They also manipulated conceptual fluency by using transparent word pairs (semantic lexemes contribute to the meaning of the words e.g., *waterfall*) and opaque word pairs (lexemes do not contribute to meaning e.g., *bulldoze*). This was to test the contribution of conceptual fluency in associative recognition. Results for both yes-no associative recognition experiments replicated the increased hit and false alarm rates with no difference in discrimination for CW pairs. Ahmad and Hockley (2017) did not find an effect of either perceptual or conceptual processing fluency for CW pairs and concluded that it was the familiarity rather than fluency that influenced responding.

Ahmad and Hockley (2017) attributed their findings to the CW effect, where word pairs with the pre-experimental familiarity result in increased hit and false alarm rates over NCW pairs, resulting in a concordant effect (Ahmad & Hockley, 2014). The CW effect is due to a greater reliance of familiarity of the associations when the pairs are unitized. Ahmad and Hockley (2014) found the CW effect for both Yes-No (YN) and Forced Choice (FC) associative recognition tasks when presenting participants with CW and NCW pairs. One of their experiments repeated NCW pairings four times compared to CW pairings for YN associative recognition. They found a mirror effect for repeated NCW pairs, where the hit rates were higher and false alarm rates were lower for repeated NCW pairs compared to CW pairs, as repeating the pairs increased recollection of the NCW pairs. The unitization of the compound word pairs was more reliant on familiarity, resulting in the concordant pattern of responding, which is characteristic of the CW effect. Repetition had a different effect on CW pairs compared to NCW pairs, as accuracy was increased for NCW pairs, but not CW pairs. Both of these studies were unable to find a discrimination difference for non-repeated CW pairs and NCW pairs in YN associative recognition, seen by a concordant effect for both pairs types (Ahmad & Hockley, 2014; Ahmad & Hockley, 2017).

In contrast to the results for yes-no associative recognition, for FC associative recognition, intact CW pairs had a higher proportion of correct responses than intact NCW pairs, as well as a discrimination advantage for CW pairs over NCW pairs (Ahmad & Hockley, 2014). Ahmad, Fernandes, and Hockley (2015) replicated this pattern of results for young adults. These findings provide evidence of differential processes used for associative recognition decisions, with FC associative recognition having a higher reliance on familiarity.

Signal Detection Theory, Yes/No and Forced Choice Recognition

The Signal Detection Theory (SDT) outlines the decision process when making recognition decisions. The model functions along a dimension of signal strength against a criterion to determine the presence or absence of a stimuli. A participant will make a decision of *yes* (present) or *no* (absent). If enough information is present for an item the signal strength will be higher. The criterion is the threshold for responding. If the signal strength is higher than the criterion, a participant will make a *yes* response. If the signal strength does not surpass the criterion, the participant will make a *no* response. A hit occurs when a participant responds *yes* when recognizing an old item. A false alarm occurs when a participant responds *yes* to a new item. A miss occurs when a *no* response is made in the presence of an old item. When a participant responds *no* to a new item, this is considered a correct rejection (Macmillan & Creelman, 1991). The ability to discriminate old and new items is based on the discrepancy between the distributions of strengths of the items. This is represented by *d*' which specifies the distance between the means of the old and new distributions. If an old item is similar in strength to a new item, the likelihood of discriminating is less, represented by a low *d*' value. A larger *d'* value occurs when the difference in the signal strength of old and new items is larger, resulting in easier discrimination (Macmillan & Creelman, 1991).

SDT for associative recognition outlines that when a participant is making an recognition decision, the familiarity of both the associations (*A*) and the individual items (*I*) are considered against a decision criterion (*c)* (Hockley, 1992). The sum of the familiarity of *A* and *I* must be greater than *c* to make an old response. A new response is made when the sum of familiarity value is less than *c*. In order to make a correct associative recognition response, participants must rely on the presence of *A* information, because *I* adds to the familiarity, but not to discrimination. A false alarm occurs when the familiarity of *I* exceeds *c*. SDT quantifies the probability of making a recognition decision based on signal strength.

Recollection and familiarity both have an influence on associative recognition. Yonelinas (1997) investigated the relationship between item and associative information for familiarity and recollection. Yonelinas (1997) manipulated the difficulty of recall-to-reject by pairing words with one other word or with multiple words during the study list. Recollecting only one of the words from a word pair that was presented with multiple words during study would then not suffice in determining an old intact pair. This was done to combine a SDT familiarity-based process with an absolute threshold recollection-based process. The familiarity-based process states that familiarity is used as an index of signal strength, which is based on the internal memory trace of the strength of the pairing (Hockley, 1992). That is, the familiarity acts as a gradient measure based on the signal strength of the item and associative information. Familiarity of the item information can influence responses, but it is the familiarity of the associative information, which increases the strength of the associative information, that results in accurate responding. The greater the familiarity of the associations, the more likely the participant will make an old response. The recollection-based process views recollection of the associative information as an absolute threshold based on an all-or-none process, where either participants recall pairings based on the strength of the associations or do not recall (Yonelinas, 1997). When the specific information of the associations is recalled, the participant will make an old response. If the participant cannot recall the associative information, they will make a new response. Where recollection is based on the presence or absence of the associative information, familiarity is based on a graded strength of the item and associative information. When participants cannot recollect the associative information, decisions are then based on familiarity of the item and associative information. Since the associative information is specific to the individual word pairings, the familiarity strength of the items alone cannot be used to make an accurate decision. Both processes are used in memory judgements, but recollection of the association results in more accurate responding.

Associative recognition utilizes two test procedures when evaluating memory; Yes/No (YN) and Forced Choice (FC). YN tasks present participants with one pairing at a time at test. Participants must make a memory judgement by responding to the pair as an old previously presented pair (intact) or a new distractor (rearranged) based on the question “have you seen this before?”. FC presents participants with two (or more) options. Participants must respond by correctly choosing the intact pair, avoiding the rearranged pairs. SDT assumes that both of these types of tests are equally sensitive in assessing discrimination accuracy for item and associative recognition.

Ahmad and Hockley (2014) compared FC and YN associative recognition tasks for discrimination of compound word (CW) pairs and non-compound word (NCW) pairs. During study, participants were presented with both CW and NCW pairs. The CW effect states that the unitization based on the pre-experimental semantic information in CW pairs is more reliant on familiarity (Ahmad & Hockley, 2014). The use of CW pairs acted as a familiarity manipulation, where NCW pairs were less familiar based on their lack of pre-experimental familiarity. Since recognition of CW pairs is reliant on the familiarity of the associations, this would facilitate for more use of familiarity-based associative recognition decisions, rather than a recollection recall-based strategy. Ahmad and Hockley (2014) found a concordant effect for YN associative recognition, with no overall difference in discrimination. The unexpected finding was that a discrimination advantage for the CW pairs was found in tests of FC associative recognition.

Ahmad, Fernandes, and Hockley (2015) tested associative recognition of younger and older adults for CW and NCW pairs in a procedure similar to Ahmad and Hockley (2014). They found a discrimination advantage for CW over NCW pairs in both YN and FC recognition tests for older adults, as they were relying more on familiarity when making associative recognition judgements. They also replicated the discrimination advantage found by Ahmad and Hockley (2014) for FC over YN recognition for younger adults (Ahmad et al., 2015). This study provided evidence that test type affected how familiarity was utilized differently when younger and older adults make associative recognition decisions. Evidence of the reliance in favor of familiarity when comparing YN and FC recognition has been seen in older participants (Ahmad, Fernandes, & Hockley, 2015; Bastin & Van der Linden 2003), amnesics (Giovanello, Keane, & Verfaellie, 2006; Khoe et al., 2000), and hippocampal lesion studies (Bayley, Wixted, Hopkins, & Squire, 2008). These results suggest a difference in test sensitivity was the result of different information being used to make recognition decisions. Familiarity is used as the basis for recognition to a greater extent by young and old subjects performing a FC task, and recollection is used more often by young adults as a basis for recognition decisions in a YN task.

Previous Research and Discrimination Advantage

A previous study was conducted by Schliewinsky and Hockley (2016) that examined the effects of manipulating the familiarity of random word pairs on associative recognition for FC and YN recognition tests similar to the procedures of Ahmad and Hockley (2014). Familiarity was manipulated by adding a familiarization list of word pairs before the study list, similar to the Greene (1999) item familiarity procedure. In the familiarity list, word pairs were presented twice before the study list is shown. Participant were given either a FC or a YN recognition test. Results of this experiment are shown in Table 1.

Table 1. *Results of the Schliewinsky and Hockley (2016) study this research is based upon. Displayed are the proportion of old responses for the YN, proportion of correct responses for FC, and the d' values when comparing the conditions, with standard deviations in parenthesis.*

	Yes/No Condition	
	Word Pair Type	
Word Pair Condition	Intact	Rearranged
Familiarized	0.861 (1.242)	0.355 (1.652)
Unfamiliarized	0.592 (1.790)	0.237 (1.433)
	Forced Choice Condition	
	Intact Word Pairs	
Rearranged Word Pairs	Familiarized (FI)	Unfamiliarized (UI)
Familiarized (FR)	0.920 (1.065)	0.697 (1.677)
Unfamiliarized (UR)	0.901 (1.182)	0.795 (1.422)
	Comparison of YN and FC *d*'	
	Test Type	
Word Pair	YN	FC
Familiarized	2.164 (1.715)	3.256 (1.312)
Unfamiliarized	1.386 (1.626)	1.387 (1.240)

Increasing the familiarity of the word pairs increased recognition accuracy for both FC and YN recognition, but the increase in accuracy was much greater for FC recognition. Such effects for familiarized pairs compared to unfamiliarized pairs provide evidence participants were using different decision processes to inform their YN and FC recognition decisions.

When familiarity was increased in the FC condition, the comparative familiarity of the intact pairs was increased, resulting in more accurate memory. The FC recognition condition has the participants comparing two options based on relative associative strength. The familiarized pairs increased this strength of the association, allowing for more accurate memory. For the YN recognition condition, participants needed to recollect the association of the word pairs to accurately respond. This increased familiarity increased correct old responses, just not to as great an extent as for FC recognition. Schliewinsky and Hockley (2016) suggested that FC recognition decisions are more reliant on familiarity than YN recognition. When the experimental familiarity was increased for word pairs, this increased the likelihood of recalling the correct associations, allowing for more accurate responding. It was the combination of greater influence of familiarity and recollection that resulted in the discrimination advantage for FC.

This discrimination differences between YN and FC associative recognition found by Schliewinsky and Hockley (2016), in addition to the other studies (see Ahmad & Hockley, 2014; Ahmad et al., 2015), have major implications for the SDT, which assume that YN and FC recognition are measures of equal sensitivity. The findings of these studies provide some contradiction to the notion that both FC and YN recognition tasks have equal sensitivity in assessing associative recognition memory. The difference in processing in YN and FC tasks when familiarity is manipulated has resulted in differences in performance. Thus, signal detection theory cannot be used as an accurate means of comparing associative recognition performance when familiarity of the associative strength is increased. Researcher must take into account these differences.

Current Research

Few studies have directly compared YN and FC recognition and the studies that have found a difference in discrimination between the two types of associative recognition tests when there was a difference in familiarity. This finding, if it is a replicable and general finding, poses a problem for signal detection theory which previously assumes YN and FC associative recognition procedures are equally sensitive measures for recognition memory. The aim of this study was to directly manipulate familiarity to compare the sensitivity of YN and FC associative recognition.

This research used different manipulations to test the influence of familiarity advantage for FC and YN associative recognition. There are few clear results of the influence of exclusively increased item familiarity on this discrimination advantage. Previous literature has not tested the presence of the discrimination advantage in different FC procedure for word pairs. Additionally, FC and YN recognition procedures have not been compared directly when testing the effects of increased familiarity as a within-subjects manner. In doing so, this will build upon and increase the validity of Schliewinsky and Hockley (2016). In order to further understand the effects of familiarity across FC and YN associative recognition procedures and the discrimination advantage for FC over YN recognition when familiarity is increased, three experiment were conducted to test the effects of increased item familiarity, to investigate the discrimination advantage across different FC procedures, and to provide consistency of findings for a comparison of YN and FC recognition tasks.

For Experiment 1, individual words were presented twice on the familiarization list instead of word pairs in order to test the effects of increased item familiarity on associative recognition. The following study list presented participants with word pairs containing familiarized and unfamiliarized word pairs. At test, they were given a YN or a FC associative recognition task. It was predicted that there would be no discrimination advantage present for the FC condition over the YN, as associative information must be present to make accurate memory judgements. Increased item familiarity would increase the hit rate and false alarm rate, but not affect discrimination, because only associative information can increase discrimination. This concordant effect would indicate that familiarity plays a role in associative recognition decisions, even when it is not informative.

The second experiment investigated presentation type for FC associative recognition tasks. Smith, Dunn, Baguely, & Stacey (2016) investigated voice-face associative recognition when test pairs were presented simultaneously rather than sequentially in FC tasks. Participants had to match faces and voices. They either heard a voice and were presented with two face options or saw a face then were presented with two voice options. These were presented simultaneously (presented together) or sequentially (presented one and then the other). Performances was better when face-voice matching was done in simultaneous FC rather than sequential FC conditions. The difference in performance suggests associative recognition decisions are based on differential processing strategies, where simultaneous presentation involves a familiarity-based approach, and sequential presentations involves a more recall-based recollection strategy similar to YN recognition (Finley, Roediger, Hughes, Wahlheim, & Jacoby, 2015; Smith, et al., 2016). Experiment 2 presented participants with test word pairs either simultaneously (on the screen at the same time) or sequentially (one at a time, then asked to make a response of first or second). The familiarization list consisted of word pairs, returning to the Schliewinsky and Hockley (2016) procedure to manipulate associative familiarity. This experiment acted as a halfway point when comparing the YN and the FC test procedures for associative recognition, where evidence suggests that sequential presentation is more similar to YN recognition recall-based processing (Finley et. al., 2015; Smith, et al., 2016). Experiment 2 was designed to provide evidence if participants are using strategies that are more familiarity-based or recall-based in the simultaneous and sequential tasks. Furthermore, Experiment 2 investigated how simultaneous and sequential FC tasks are affected by associative familiarity of word pairs. The results of this study are hypothesized to find a significant discrimination advantage for simultaneous over sequential FC tasks similar to Smith et al. (2016), as both test types are relying on different recognition strategies.

Finally, for Experiment 3, a replication of the previous research conducted by Schliewinsky and Hockley (2016) was conducted as a within-subjects manipulation. Instead of participants receiving either the YN or FC recognition at test, the test combined both YN and FC trials presented randomly. Word pairs were presented in the familiarization list and study list as previously done in Experiment 2 and by Schliewinsky and Hockley (2016). Using a within-subjects design would not only provide a replication of the discrimination advantage for FC over YN recognition, but will also increase the generalizability of the previous findings by investigating the discrimination advantage across more FC and YN recognition procedures. Taken together, these three experiments will serve to further the understanding of the function of increased item and associative familiarity across FC and YN associative recognition tasks, and to further investigate the circumstances of increased familiarity when the discrimination advantage of FC over YN recognition occurs.

Experiment 1: Item Familiarity

Experiment 1 investigated discrimination for FC and YN recognition when only the familiarity of individual words was increased. This experiment is based on a modified version of Schliewinsky and Hockley (2016). The principal change was that rather than familiarizing word pairs, only individual words were presented on the familiarization list. This tested the effects of increased item familiarity in associative recognition similar to studies such as Greene (1999) and Jou (2010). These individual words appeared in the word pairs within the study list. Following familiarization and study lists, participants then received either the FC or YN associative recognition tasks. It was predicted that there would be no discrimination advantage present for the FC condition over the YN, as item information cannot aid in associative discrimination (Cleary et al., 2001; Hockley, 1992; Schliewinsky & Hockley, 2016). The question of interest was whether the familiarity of individual words would influence associative recognition decisions and whether any such influence was greater for FC or YN associative recognition.

Method

Participants. Fifty-four undergraduate students enrolled in a psychology course from Wilfrid Laurier University participated in the experiment through the Departmental Research Participant Program. Participants volunteered in return for partial course credit. The participants were divided equally (27 each) between the YN and the FC test conditions.

Apparatus and Stimuli. Experiments were conducted using Superlab IV (Cedrus Corp.) software run on a laboratory PC with a 17” monitor. The software was used to control stimulus presentation and response recording. The stimuli were 140 nouns between 3 and 8 letters long from the MRC psycholinguistic database (Wilson, 1988). These words had Kucera-Francis word frequency values between 20 and 300, with familiarity, concreteness, imageability and meaningfulness values between 150 and 550. Intact word pairs were created by randomly selecting two words from the word bank, avoiding any universally known compound words. Rearranged pairs, which acted as newly presented pairs in the test phase, were created by taking parent words from the study word pairings and pairing them with another word from another pairing. Rearranged pairs consisted only of words presented in other word pairs in the experiment; no new words were introduced at test. The left-right order of the words in the intact pairs was preserved in the rearranged pairs. For example, *book cross* would be a new rearranged test pair created from the study pairs *book wall* and *print cross*.

Procedure. Participants were instructed to do their best to try to remember the word pairings and were encouraged to form associations between word pairs during the experiment, as their memory would later be tested. Participants were first shown a familiarization list, followed by a study list, then either a YN or FC associative recognition task. The words in the familiarization list and word pairings in the study and test lists were presented in the center of the screen, words 1 inch apart for pairs, black size 48 Times New Roman font, on a white background. Words and word pairings were presented in a different random order for each participant for 4 seconds in both the familiarization and study lists with no intervening interval.

Participants were instructed that they would be presented with words on the familiarization list on an instruction screen. Participants began the session pressing any key. In the familiarization list, 32 individual words were presented twice, for a total of 64 presentations. Participants were then presented with a screen of instructions for the study list until the participants were ready to proceed. The instructions indicated that the next list was the true study list. The study list consisted of 64 word pairs, with 32 familiarized pairs comprised of an unfamiliarized word and a word presented on the familiarization list and 32 consisted of new unfamiliarized word pairs. Due to a programming error, familiarized pairs contained only one familiar word and one new word. Half of words from the familiarization list were positioned first in their study pair, and the other half second. Three buffer pairs consisting of new words that were not tested were shown at the beginning of the list and three at the end to eliminate primacy and recency effects.

Participants were instructed to notify the researcher before continuing to test. Verbal instructions were provided by the researcher in order to ensure clarity. They were also provided with an instruction screen. Participants began the test once ready. Presentation order was random for each participant. Half of each type of pair consisted of a familiarized word and half consisted of unfamiliarized words. Sixteen pairs were intact and 16 pairs were rearranged. Word pairs were displayed on the screen until the participant made a response. For the YN test condition, one word pair was presented at a time for 32 presentations. Participants responded by pressing the "z" key for a new (rearranged) pairing and the "/" for an old (intact) pairing for each test pair. Response time from the onset of the presentation of the test pair to the response was also recorded.

The FC test condition list consisted of 32 presentations of an old intact pair and a new rearranged pair. Word pairs were presented at the top and bottom of the test screen. The top/bottom order of intact and rearranged pairs was random. The test types were as follows: Familiarized intact and familiarized rearranged pair (FI vs. FR), familiarized intact and unfamiliarized rearranged pair (FI vs. UR), unfamiliarized intact and familiarized rearranged pair (UI vs. FR), and unfamiliaried intact and unfamiliarized rearranged pair (UI vs. UR). Participants made a memory decision by responding to which of the two pairs they thought was the intact pair by pressing "1" for the top pairing and "2" for the bottom pairing. Response time from the onset of the presentation were recorded. The same number of test presentations was used in the YN and FC associative recognition conditions in order to equate the power.

Data analysis. The number of old responses was assessed for the YN condition, and the number of correct responses for the FC condition. Proportions of these responses were calculated by dividing the number of responses (old responses for YN, correct responses for FC) by the total number of presentations (8 each) in that word pair condition (i.e., familiarized intact pair (FI) presented with a familiarized rearranged (FR) pair for FC, familiarized intact pair for YN, etc.). The sensitivity index (*d*') is the measure of accuracy for responding based on the correct (hit rate) and incorrect responses (false alarm rate) across both the FC and the YN conditions. This value was obtained by subtracting the z-transforms of the proportions of hit and false alarm rates. This value was calculated in order to compare accuracy in the FC to the YN condition. The equation used to obtain the *d*' values was obtained in the YN condition by taking the proportion of old responses for the hit rate (h) and false alarm rate (*fa*) from each familiarization condition inputting them into the following equation in Microsoft Excel:

$$= NORMSINV(h) - NORMSINV(fa)$$

For the FC condition, the proportion of correct responses (h) was subtracted from the proportion of incorrect responses (*fa*) divided by the square root of 2 in the following equation in Microsoft Excel:

$$= (NORMSINV(h) - NORMSINV(fa))/SQRT(2)$$

Results and Discussion

YN proportion of old responses. The proportion of old responses and standard errors for the YN test condition are presented in Table 2. Overall responses for hit rates and familiarized pairs were greatest, with the most proportion of old responses occurring for familiarized intact pairs. The discrepancy between the hits and false alarms was greatest for familiarized pairs.

Table 2. *Means and standard errors for correct (hits) and incorrect (false alarms) proportions of old responses for familiarized and unfamiliarized word pairs in the Yes/No condition for Experiment 1.*

	Word Pair Condition		
Word Pair Type	Familiarized	Unfamiliarized	Mean
Hit Rate	.759 (.027)	.657 (.044)	.708 (.026)
False Alarms	.338 (.04)	.333 (.051)	.336 (.04)
Mean	.549 (.02)	.495 (.027)	

A 2 (Familiarity: familiarized vs. unfamiliarized) by 2 (Test type: intact vs. rearranged) repeated measures analysis of variance was conducted for the YN condition. A main effect was found for Test pair type, indicating that the proportion of old responses was greater for intact than rearranged pairs (i.e., the hit rate was greater than the false alarm rate) ($F(1, 26) = 45.469$, $p < .001$, $\eta_p^2 = .116$). This finding is consistent with previous associative recognition research and show overall discrimination was above chance (Schliewinsky & Hockley, 2016). There was no significant main effect for Familiarity ($F(1, 26) = 3.410$, $p = .076$, $\eta_p^2 = .636$) or interaction between Familiarity and Test type, ($F(1, 26) = 1.471$, $p = .236$, $\eta_p^2 = .054$), indicating that the increased familiarity of word pairs did not result in significantly better recognition of pairs. The trend for higher old responses for familiarized pairs does show that there is some influence of item familiarity on associative recognition. This suggests that participants in the YN tasks rely more on a recollection based strategy rather than familiarity when making recognition decisions. Since associative familiarity was not manipulated, increased item familiarity did not allow for a significant advantage for familiarized pairs.

FC proportion of correct responses. Table 3 displays the mean proportion of correct responses for each trial type in the FC test condition. Overall means were highest for trials that contained a familiarized intact pair. The greatest number of correct responses occurred on trials where a familiarized intact pair and an unfamiliarized rearranged pair were tested. Participants were more like to choose the familiarized pair when it was paired with an unfamiliarized pair. This indicates that although associative familiarity and/or recollection must be present for accurate responding, increased item familiarity still influenced memory judgements. When the familiarity was present for the rearranged pairs, this created conflicting information and resulted in lower correct responses.

Table 3. *Means and standard errors for the proportion of correct responses in the Forced Choice condition for each presentation trial type for Experiment 1.*

	Intact Word Pairs		
Rearranged Word Pairs	Familiarized (FI)	Unfamiliarized (UI)	Means
Familiarized (FR)	.727 (.038)	.657 (.036)	.692 (.029)
Unfamiliarized (UR)	.796 (.028)	.699 (.037)	.748 (.026)
Means	.762 (.025)	.678 (.030)	

A 2 (familiarized vs. unfamiliarized intact pairs) by 2 (familiarized vs. unfamiliarized rearranged pairs) repeated measures analysis of variance was conducted for the FC test condition. A main effect was found for familiarized intact pairs, indicating that participants were more likely to recognize test probes where the intact pairs contained the familiarized item from the initial familiarization list ($F(1, 26) = 7.61$, $p = .01$, $\eta_p^2 = .226$). There was also a trend for a main effect of familiarized rearranged pairs that did not reach significance, ($F(1,26) = 3.328$, $p =$

.08, η_p^2 = .113). No interaction between intact and rearranged pairs was found (F(1, 26) = .194, p = .663, η_p^2 = .007). The effect of familiarity on intact pairs was independent of familiarity of the rearranged pairs.

Comparison of YN and FC *d'*. Mean *d'* values and standard errors for each test condition are presented in Table 4. Overall means were highest for familiarized pairs and in the YN condition. Highest *d*' values occurred for trials in the YN condition with familiarized pairs. The discrepancy between values was greatest in the YN condition and for unfamiliarized pairs.

Table 4. *Mean d' values and standard errors for comparing the YN and FC conditions for familiarized and unfamiliarized word pairs for Experiment 1.*

	Word Pair Condition		
Test Type	Familiarized	Unfamiliarized	Means
Yes/No	1.833 (.401)	1.565 (.391)	1.699 (.316)
Forced Choice	1.686 (.263)	.979 (.226)	1.333 (.218)
Means	1.760 (.2)	1.272 (.236)	

Using the *d*' measure, a 2 (familiarized vs. unfamiliarized) by 2 (YN vs. FC tests) mixed factor analysis of variance was conducted to compare the YN to the FC task. There was no significant main effect of test type, (F(1,26) = .776, p = .387, η_p^2 = .029). The was a trend for a main effect of familiarity that fell short of significance, (F(1,26) = 3.422, p = .076, η_p^2 = .116). The interaction between these variables did not approach significance (F(1,26) = .689, p = .414, η_p^2 = .026).

This pattern of results is inconsistent with Schliewinsky and Hockley (2016), where FC had the greatest *d*' values and higher discrepancy between familiarized and unfamiliarized word pairs. That pattern is indicative of accurate memory influenced by the increased familiarity strength of the associations. Schliewinsky and Hockley (2016) found a significant effect for familiarity and an interaction between familiarity and test condition when word pairs were familiarized rather than an individual word in the word pairs. Schliewinsky and Hockley (2016) concluded that the discrimination advantage found for FC over YN recognition suggests that these studies use different recognition decision processes. The lack of discrepancy between the *d*' values in the YN recognition condition indicates that increased item familiarity did not result in accurate responding in for familiarized versus unfamiliarized pairs. The increased item familiarity did not provide the necessary information required for accurate responding. This compared to FC, where the increased item familiarity increased responding for intact pairs, resulting in a trend in greater discrepancy of *d*' values. This trend in the differences in discrepancy for the FC and YN recognition conditions suggests that increasing item familiarity differentially influences responding for these recognition tasks. Additionally, this inconsistency with Schliewinsky and Hockley (2016) emphasizes the importance of the familiarity of the associative information and recollection of the specific associations that are needed for accurate responding.

There was found to be no discrimination advantage present for the FC test condition over the YN test condition, as accurate judgements must be based on associative information and not item familiarity (Hockley, 1992; Cleary et al., 2001). According to the Signal detection theory for associative recognition, it is associative information that results in correct recognition, but item familiarity could influence the proportion of old responses for intact and rearranged pairs (Hockley, 1992). These findings also verify that associative information must be present to see this discrimination advantage demonstrated by Schliewinsky and Hockley (2016), where associative familiarity and item familiarity was increased.

Response times. Participants were not informed that reaction time was a priority. Response times for correct responses in the YN and FC test conditions are displayed in Table 5. The mean response times for the YN test are faster than those of the FC test due to the characteristics of the test procedures, as YN recognition only requires participants to respond to one pair compared to the two pairs in FC recognition.

Table 5. *Means and standard errors of response times for correct responses in the YN and FC conditions for each trial type in milliseconds in Experiment 1.*

	Yes/No Condition		
	Word Pair Condition		
Word Pair Type	Familiarized	Unfamiliarized	Mean
Hit Rate	2052 (119)	2105 (150)	2078 (117)
False Alarms	2995 (253)	2454 (169)	2724 (176)
Mean	2523 (160)	2279 (124)	
	Forced Choice Condition		
	Intact Word Pairs		
Rearranged Word Pairs	Familiarized (FI)	Unfamiliarized (UI)	Means
Familiarized (FR)	3652 (222)	3616 (223)	3634 (189)
Unfamiliarized (UR)	3479 (206)	3343 (165)	3411 (162)
Means	3565 (196)	3450 (180)	

A 2 (familiarized vs. unfamiliarized) by 2 (intact vs. rearranged) repeated measures ANOVA was conducted for the response times for YN recognition. A significant main effect was found for test pair type (F(1, 26) = 16.083, p < .001, η_p^2 = .382), indicating that intact pairs were correctly responded to faster than rearranged pairs. No main effect of familiarity, (F(1, 26) = 3.278, p = .082, η_p^2 = .112), or an interaction, (F(1, 26) = 4.047, p = .055, η_p^2 = .135), were found. A 2 (familiarized vs. unfamiliarized intact pairs) by 2 (familiarized vs. unfamiliarized rearranged pairs) repeated measures ANOVA was conducted for FC recognition response times. There were no main effects for intact familiarity, (F(1, 26) = .239, p = .629, η_p^2 = .009), rearranged familiarity, (F(1, 26) = 4.113, p = 053, η_p^2 = .137), or an interaction, (F(1, 26) = 1.808, p = .678, η_p^2 = .007), indicating that responses times did not differ significantly between FC test conditions

Discussion. For each analysis, there is a trend of familiarized intact pairs having a higher proportion of old responses when compared to their unfamiliarized counterparts in YN recognition. The effect of familiarity of intact pairs was significant in the FC test condition. No concordant trend in the YN recognition condition was observed, as there was no difference in the familiarized and unfamiliarized false alarm rates for the proportion of old responses. A main effect for familiarized intact word pairs was found for the FC condition, but there was only a trend for familiarity for the YN recognition condition. This suggests that increased item familiarity influences more old responses in the FC recognition condition than in the YN recognition condition. This does not equate to more overall accurate responding, nor was there a significant advantage in YN recognition condition, as accurate responding is reliant on associative strength (Hockley, 1992).

It could be noted that (a) the finding of a trend for the effect of item familiarity in YN and a significant effect for intact pairs in FC show that familiarity plays a role in associative recognition decisions, and (b) that the effect of item familiarity was only reliable in FC tests suggests familiarity may play a larger role in FC recognition decisions. These findings were in spite of the intention to include two familiarized words in the familiarized word pairs in the study list rather than just one word. Future research should test the intended procedure of familiarizing items and presenting both words in the word pairs on the study list.

The familiarity of individual words may increase the familiarity of a pair, which influences responding (see Jou, 2010). However, this type of familiarity does not assist in discrimination of old and new pairs, hence the lack of a discrimination advantage. Familiarity and recollection of associative information, rather than item information, is key when making correct recognition decisions for both YN and FC recognition tasks. It is combination of the words that creates the necessary associative information that is necessary for participants to discriminate previously presented word pairs and new rearranged pairs (Ahmad & Hockley, 2017; Cohn & Moscovitch, 2007; Lloyd et al., 2015). Experiment 1 emphasizes the importance of associative strength of pairs to make accurate responses. Increased item familiarity has an effect on responding, but does not provide any significant discrimination advantage for YN or FC associative recognition. When Schliewinsky and Hockley (2016) familiarized pairs, they were not only increasing the familiarity of the items, but the associative strength. This is why they found a discrimination advantage for FC over YN in associative recognition.

Experiment 2: Simultaneous vs. Sequential FC Presentation

The second experiment investigated presentation format for FC associative recognition tasks. Smith et. al. (2016) found evidence of increased accuracy in voice-face associative recognition when test pairs were presented simultaneously rather than sequentially. This may be due to the fact that faces and voices are typically perceived simultaneously rather than sequentially in social situations (Smith et al, 2016). Experiment 2 presented participants with test word pairs in a FC associative recognition procedure either simultaneously (on the screen at the same time) or sequentially (one at a time, then asked to make a response of first or second). The familiarization list consisted of word pairs, returning to the procedure of Schliewinsky and Hockley (2016). This will re-introduce the manipulation of associative familiarity, which is necessary for accurate responding.

The purpose of this experiment was to investigate the presence of any discrimination advantages for these two different FC tasks. This experiments acted as a halfway point between the YN and the FC test procedures for associative recognition, as it investigated another facet of sensitivity for test pair presentation. In YN associative recognition, participants may rely more on recollection than familiarity whereas in FC recognition, participants may be more influenced by the familiarity of each word pair. Presenting the FC test alternatives sequentially rather than simultaneously might lead participants to shift from a more familiarity-based to a more recall-based recognition strategy. Primarily, this study was designed to provide evidence in determining if participants are using the strategies more similar to YN or FC recognition when testing in the sequential condition. This experiment also further investigated which test manipulation is more affected by increased familiarity of associative information of word pairs. There should be a significant discrimination advantage for recognition for the simultaneous FC compared to the sequential FC task, as it is hypothesized that participants have a greater reliance on familiarity in the simultaneous condition compared to the sequential condition.

Method

Participants. Fifty-four undergraduate students enrolled in a psychology course from Wilfrid Laurier University participated in the experiment through the Departmental Research

Participant Program. Participants volunteered in return for partial course credit. The participants were divided equally (27 each) between the sequential and simultaneous test conditions.

Apparatus and Stimuli. All apparatus and stimuli were similar to Experiment 1. A different word list with the same features was used for this experiment to increase the generalizability of the findings.

Procedure. The procedure was similar to Experiment 1. The principal differences were that participants only completed a familiarization list and one of the two FC tasks. The initial familiarization list consisted of to-be-remembered word pairs rather than individual words in order to increase both item and associative familiarity. All other aspects of the study list was the same as Experiment 1.

Participants were randomly assigned to either the simultaneous or sequential FC test condition. The simultaneous test condition was conducted in the same manner as the FC test in Experiment 1. In the sequential test condition, one word pair was presented in the center of the screen for 4 seconds before immediately transitioning to the second word pair, also presented for 4 seconds. A screen then appeared asking “First (1) or Second (2)?” prompting participants to press either the “1” key or the “2” key in respect to which pair they recognized previously on the study list. The next sequence of pairs was presented once the participant made a response.

Results and Discussion

Table 6 displays the mean proportion of correct responses, *d*’ values, response times, and standard errors for each trial type in the simultaneous condition and the sequential condition, in addition to the marginal means of each measure.

Table 6. *Means and standard errors for the proportion of correct responses, d' values, and response times in milliseconds (RT) in the Simultaneous and Sequential Forced Choice condition for each presentation trial type. Marginal means are displayed below.*

	Simultaneous Condition			Sequential Condition		
Trial Type	Proportion Correct	*d*'	RT	Proportion Correct	*d'*	RT
FI vs. FR	.907 (.021)	3.937 (.529)	2948 (198)	.866 (.041)	3.935 (.582)	8629 (53)
FI vs. UR	.880 (.028)	3.489 (.533)	3303 (246)	.880 (.031)	4.148 (.569)	8835 (94)
UI vs. FR	.662 (.045	1.038 (.358)	3955 (320)	.704 (.033)	1.010 (.257)	8785 (83)
UI vs. UR	.769 (.693)	2.142 (.495)	3824 (335)	.796 (.038)	2.446 (.512)	8968 (104)
FI	.894 (.022)	3.713 (.412)	3125 (205)	.873 (.032)	4.041 (.505)	8732 (64)
UI	.715 (.035)	1.590 (.306)	3890 (275)	.750 (.033)	1.728 (.316)	8876 (74)
FR	.785 (.02)	2.487 (.344)	3451 (212)	.785 (.033)	2.472 (.357)	8707 (57)
UR	.824 (.031	2.816 (.369)	3563 (247)	.838 (.031)	3.297 (.441)	8901 (75)

Note. Familiarized Intact (FI), Unfamiliarized Intact (UI), Familiarized Rearranged (FR), and Unfamiliarized Intact (UI).

Proportion of correct responses. A 2 (simultaneous vs. sequential test type) by 2 (familiarized vs. unfamiliarized intact) by 2 (familiarized vs. unfamiliarized rearranged) mixed model measures ANOVA was conducted, with test type as the between-subjects variable. No main effect was found for test type ($F(1, 26) = .026$, $p = .872$, $\eta_p^2 = .001$), indicating no difference in performance in the simultaneous and sequential tests. Main effects were found for intact pair familiarity ($F(1, 26) = 58.948$, $p < .001$, $\eta_p^2 = .694$) and rearranged pair familiarity ($F(1, 26) = 9.706$, $p = .004$, $\eta_p^2 = .272$). An interaction was also found for familiarity of intact versus rearranged pairs, ($F(1, 26) = 9.112$, $p = .006$, $\eta_p^2 = .260$). Trials with familiarized intact pairs were recognized better than those with unfamiliarized intact pairs. Trials containing unfamiliarized rearranged pairs resulted in better recognition than those containing familiarized rearranged pairs. Based on the interaction of these pair types, participants' accuracy was greatest for trials containing familiarized intact pairs and unfamiliarized rearranged pairs. No three way interaction was found, ($F(1, 26) = .785$, $p = .384$, $\eta_p^2 = .029$), indicating that test condition had no effect on the discrimination advantage for intact and rearranged pairs based on familiarity. This lack of interaction provides evidence that participants were using a similar recognition strategy for these two FC tasks.

Trials containing a familiarized intact pair versus an unfamiliarized rearranged pair were more correctly recognized since the familiarity of the intact pair increased the strength of the association, leading to more accurate recognition. Unfamiliarized rearranged pairs were easier to reject because of their lower familiarity. In trials containing an unfamiliarized intact pair versus a familiarized rearranged pair, the familiarity of the rearranged pair conflicts with the unfamiliarized intact pairs. This familiarity influenced participants to respond to the rearranged pair. Only familiarized item information is present for the rearranged pair participants. The increased familiarity of the rearranged pair would influence participants to respond to the familiarized rearranged pair rather than the unfamiliarized intact pair. Participants must recollect the unfamiliarized intact pair with the presence of the conflicting familiarity of the rearranged pair, leading to more incorrect responses.

***d'* comparison.** The same 2 (simultaneous vs. sequential test type) by 2 (familiarized vs. unfamiliarized intact) by 2 (familiarized vs. unfamiliarized rearranged) mixed factor ANOVA was conducted with the *d*' measure. To reiterate, *d*' is a measure of the participants ability to discriminate old from new word pairs. The findings were identical to the analysis of proportion correct. No main effect of test type was found, (F(1, 26) = .204, p = .655, η_p^2 = .008), indicating that test type did not differ in performance. Main effects were found for intact pair familiarity, (F(1, 26) = 102.483, p <.001, η_p^2 = .798), and rearranged pair familiarity, (F(1, 26) = 5.011, p = .034, η_p^2 = .162), reaffirming that participants were better able to discriminate familiarized intact and unfamiliarized rearranged pairs from their counterparts. The same interaction between intact and rearranged pairs was found, (F(1, 26) = 4.34, p = .047, η_p^2 = .143). No three way interaction was found, (F(1, 26) = .077, p = .784, η_p^2 = .003). These findings reinforce the idea that test type did not differ in discriminability. Rather it was familiarity of the intact pairs and the unfamiliarity of the rearranged pairs that resulted in more accurate recognition.

Response Times. A similar 2 (simultaneous vs. sequential test type) by 2 (familiarized vs. unfamiliarized intact) by 2 (familiarized vs. unfamiliarized rearranged) mixed measures ANOVA was conducted for correct response times. A main effect was found for test type, (F(1, 26) = 485.012, p < .001, η_p^2 = .949), indicating responding was faster in the simultaneous condition than the sequential condition. A main effect was found for intact pair familiarity, (F(1, 26) = 11.942, p = .002, η_p^2 = .315), indicating that familiarized intact pairs were responded to faster than unfamiliarized pairs. An interaction was found for test type and intact pairs, (F(1, 26) = 5.776, p = .024, η_p^2 = .182), indicating that trials with familiarized intact pairs were responded to faster in the simultaneous condition than the sequential condition. This interaction provides some evidence of different response strategies or that participants were faster to implement the same strategy in the simultaneous condition. It is more likely that response times for the sequential condition were longer due to the characteristics of the test. Participants had to wait at least 8 seconds to respond due to the two 4 second presentations of the word pairs.

Discussion. The findings for the simultaneous condition replicate the FC experiment conducted by Schliewinsky and Hockley (2016), as well as the findings of other FC associative studies (see Ahmad, et al., 2015; Ahmad & Hockley, 2014). The pattern of results is similar to Schliewinsky and Hockley (2016), as the highest proportion of responses are occurring for trials presented with a familiarized intact pair versus a familiarized rearranged pairs. The familiarized intact pair contains both associative and item familiarity and the familarized rearranged pair contains item familiarity. Participants could recall-to-reject the rearranged pair, offsetting the increased familiarity of the rearranged pair. In the sequential condition, the greatest proportions are for the trials containing a familiarized intact pair and an unfamiliarized rearranged pair, which is more consistent with other FC recognition studies, where the familiarity of the intact pair will assist in correct recognition in the presences of the rearranged pair, which contains weaker familiarity (Ahmad, et al., 2015; Ahmad & Hockley, 2014).

Experiment 2 did not find a discrimination advantage for simultaneous FC over sequential FC presentation when familiarity of word pairs was increased. This study also failed to replicate the discrimination advantage Smith et al. (2016) found for simultaneous FC over sequential FC in face-voice matching procedures. This could be due to the types of stimuli used, as this study investigated word pairs and not face-voice matching. Smith et. al. (2016) attributed the discrimination advantage for simultaneous presentation because social interactions usually have voices and faces present together. The two word pairs tested against each other have less relation to each other unlike faces and voices, in which the associations between the face and voice are required to make a correct response. Both tests rely on a relative comparison of familiarity strength, but the judgements made by the participants in sequential presentation condition must compare the second pair with the short term memory representation of the first pair. Having the direct references to the word pairs simultaneously present gave the participants a more direct comparison of relative familiarity. Reaction times provided a significant difference in the test types for familiarity of intact pairs, implying some difference in the time it took participants to respond. Response times are likely due to the procedural structure of the test. The simultaneous test could be “easier” when making correct recognition decisions due to the persistent viewing of pairs in the simultaneous rather that the abrupt presentations in the sequential. However, the discrimination advantage for simultaneous over sequential FC was not found for word pairings.

Experiment 3: Within Replication

Experiment 3 was a replication of the previous research conducted by Schliewinsky and Hockley (2016) but as a within-subjects measure, combining YN and FC recognition tasks. Replicating the FC recognition discrimination advantage in a within-subject design would increase the generalizability of Schliewinsky and Hockley (2016). Word pairs were presented in the familiarization list to increase associative familiarity, followed by familiarized and unfamiliarized pairs in the study list as previously described. At test, participants received both YN and FC test trials. It was hypothesized that the same discrimination advantage for FC over YN recognition similar to Schliewinsky and Hockley (2016) would be replicated.

Method

Participants. Twenty-nine undergraduate students enrolled in a psychology course from Wilfrid Laurier University participated in the experiment through the Departmental Research Participant Program. Participants volunteered in return for partial course credit. An equal number of participants (14) randomly received one of two counterbalanced versions of the experiment, both containing the mixed FC and YN tests. One participant's data was not used, as they were caught writing down word pairs during study.

Apparatus and Stimuli. All apparatus and stimuli were similar to Experiment 1 and 2. A different word list with the same word characteristic was used for this experiment to increase the generalizability of the findings.

Procedure. The procedure was similar to the previous experiments with a few modifications. The procedure for the familiarization and study list was the same in Experiment 2: 32 word pairs presented twice, followed by 64 tested study presentations consisting of 32 familiarized and 32 unfamiliarized word pairs. For the test trial, participants received a combined FC and YN associative recognition test. This test list contained 16 FC (2 word pairs per trial) and 32 YN trials for a total of 48 trial presentations, with 64 word pair presentations. Sixteen of the YN pairs were intact, and sixteen were rearranged, where half in each category were familiarized and the other half were unfamiliarized (8 each). For the FC test, the test trials consisted of 4 familiar intact/familiar rearranged pairs (FI vs. FR), 4 familiar intact/unfamiliar rearranged pairs (FI vs. UR), 4 unfamiliar intact/familiar rearranged pairs (UI vs. FR), and 4 unfamiliar intact/unfamiliar rearranged pairs (UI vs. UR). This was done to have an equal number of word pairs used in test presentations for both the FC and YN recognition tests, since FC trials contain two word pairs and YN trials contains one word pair. Which word pairs that were presented in the YN and FC tests were counterbalanced across participants.

Results and Discussion

YN proportion of old responses. The same analyses previously for Experiment 1 were conducted for the YN and the FC tests. Table 7 displays the means and standard errors of the proportion of old responses for the YN trials. Means were greatest for the familiarized pairs. The pattern of results was similar to the pattern observed by Schliewinsky and Hockley (2016).

Table 7. *Means and standard errors for hits and false alarms based on the proportion of old responses for familiarized and unfamiliarized word pairs in the Yes/No trials for Experiment 3.*

	Word Pair Condition		
Word Pair Type	Familiarized	Unfamiliarized	Mean
Hit Rate	.836 (.033)	.496 (.042)	.666 (.031)
False Alarms	.349 (.043)	.228 (.041)	.289 (.035)
Mean	.593 (.019)	.362 (.026)	

A 2 (familiarized vs. unfamiliarized pairs) by 2 (intact vs. rearranged pairs) repeated measures ANOVA was conducted for the YN condition. The main effect for familiarity was significant, ($F(1, 28) = 46.019$, $p < .001$, $\eta_p^2 = .622$), indicating that familiarized pairs were recognized better than unfamiliarized pairs. The main effect for test pair type was also significant, ($F(1, 28) = 41.127$, $p < .001$, $\eta_p^2 = .595$), indicating that the hit rate was greater than the false alarm rate. An interaction was also found between familiarity and test pair type, ($F(1, 28) = 13.851$ $p = .001$, $\eta_p^2 = .331$). This interaction shows that the difference in hit rates was greater than the difference in false alarm rates for familiarized versus unfamiliarized pairs. These findings are consistent with Schliewinsky and Hockley (2016), providing further evidence of the effects of increased familiarity for YN tasks. The main difference was that this study found an interaction for the YN trials, whereas this interaction in Schliewinsky and Hockley's results only approached significance ($p = .062$). There is a concordant effect seen in the familiar trials compared to the unfamiliarized trials. This indicates that increased familiarity is influencing more old responses for familiarized intact and rearranged word pairs compared to unfamiliarized pairs.

FC proportion of correct responses. Table 8 displays the proportion of correct responses for the FC trials. The familiarized intact word pairs had the greatest mean proportion of correct responses in trials also containing a unfamiliarized rearranged pair. The pattern of means is similar to Schliewinsky and Hockley (2016), as the greatest amount of correct responses occurred for familiarized pairs.

Table 8. *Means and standard errors for the proportion of correct responses in the Forced Choice trials for each presentation trial type in Experiment 3.*

	Intact Word Pairs		
Rearranged Word Pairs	Familiarized (FI)	Unfamiliarized (UI)	Means
Familiarized (FR)	.819 (.037)	.655 (.053)	.737 (.034)
Unfamiliarized (UR)	.871 (.027)	.629 (.054)	.750 (.032)
Means	.845 (.025)	.642 (.039)	

A 2 (familiarized vs. unfamiliarized intact pairs) by 2 (familiarized vs. unfamiliarized rearranged pairs) repeated measures ANOVA was conducted for the FC condition. Only a main effect was found for the familiarized intact condition, indicating that the proportion of correct responses was greater for trials with familiarized than unfamiliarized intact pairs, ($F(1, 28) = 22.492$, $p < .001$, $\eta_p^2 = .445$). There was no main effect for rearranged pair familiarity, ($F(1, 28) = .096$, $p = .759$, $\eta_p^2 = .003$), nor was there an interaction, ($F(1, 28) = .887$, $p = .354$, $\eta_p^2 = .031$). These results are also seen in Schliewinsky and Hockley (2016), providing more evidence to the influence of increased associative strength of intact word pairs in FC trials. This effect of intact pair familiarity provides evidence that participants are correctly recalling the intact pairs and recalling-to-reject the rearranged pairs.

Comparison of YN and FC *d'*. Table 9 displays the mean *d*' estimates for YN and FC tests. Mean *d'* was greatest for the familiarized trials in the FC trial condition.

Table 9. *Mean d' values and standard errors for the YN and FC trials for familiarized and unfamiliarized word pairs for Experiment 3.*

	Word Pair Condition		
Test Type	Familiarized	Unfamiliarized	Means
Yes/No	3.132 (.55)	1.352 (.379)	2.242 (.404)
Forced Choice	3.745 (.431)	1.705 (.459)	2.725 (.344)
Means	3.438 (.393)	1.528 (.331)	

A 2 (familiarized vs. unfamiliarized) by 2 (YN vs. FC test trials) repeated measures ANOVA was conducted to compare YN and FC recognition discrimination performance. A main effect was found for familiarity, ($F(1, 28) = 26.163$, $p < .001$, $\eta_p^2 = .483$), indicating that familiarized pairs were recognized better across both test trial types. No main effect was found for test trial type, ($F(1, 28) = 1.327$, $p = .259$, $\eta_p^2 = .045$), showing no significant difference of discrimination for FC or YN recognition. No interaction was found, ($F(1, 28) = .121$, $p = .731$, $\eta_p^2 = .004$), indicating no discrimination advantage for increased associative familiarity between FC and YN test trials. This lack of interaction is inconsistent with the Schliewinsky and Hockley (2016), where they had a significant interaction ($p = .015$), indicating a discrimination advantage for FC over YN recognition when familiarity was increased. This is also inconsistent with the findings by Ahmad and Hockley (2014) and Ahmad et al., (2015), where both found evidence of a similar discrimination advantages for FC compared to YN recognition in their comparisons of compound versus non-compound word pairs. The failure to find a discrimination advantage for FC compared to YN recognition in the within-subject design of Experiment 3 may have been due to a decrease in statistical power in the FC test condition. This possibility will be considered in the discussion section.

Response Times. Mean response times for correct responses in the YN and FC condition are displayed in Table 10. Overall response times were faster for YN tests than for FC tests, again, due to the characteristics of the test presentations, where the YN test trials only presented one word pair, and the FC test trials presented two word pairs.

Table 10. *Means and standard errors of response times for correct responses in the YN and FC conditions for each trial type in milliseconds in Experiment 3.*

	Yes/No Recognition		
	Word Pair Condition		
Word Pair Type	Familiarized	Unfamiliarized	Mean
Intact	2440 (129)	2601 (167)	2520 (134)
Rearranged	3245 (258)	2874 (212)	3059 (199)
Mean	2842 (166)	2737 (175)	
	Forced Choice Recognition		
	Intact Word Pairs		
Rearranged Word Pairs	Familiarized (FI)	Unfamiliarized (UI)	Means
Familiarized (FR)	4391 (416)	4731 (453)	4561 (311)
Unfamiliarized (UR)	3890 (249)	4688 (302)	4289 (208)
Means	4141 (256)	4710 (287)	

A 2 (familiarized vs. unfamiliarized) by 2 (intact vs. rearranged) repeated measures ANOVA was conducted for the response times for YN recognition. A significant main effect was found for test pair type, ($F(1, 28) = 11.574$, $p = .002$, $\eta_p^2 = .292$), showing that response times for intact pairs were faster than rearranged pairs. Familiarity did not significantly influence response times, as a main effect was not found for familiarity, ($F(1, 28) = .434$, $p = .516$, $\eta_p^2 = .015$). The difference between response times for intact and rearranged pairs was significantly different when pairs were familiarized rather than unfamiliarized as indicated by a significant interaction between these variables, ($F(1, 28) = 4.723$, $p = .038$, $\eta_p^2 = .144$). The difference in discrimination for familiarized intact pairs compared to familiarized rearranged pairs was faster than the differences for discriminating unfamiliarized intact and rearranged pairs, where familiarized intact pairs were correctly responded to the fastest.

A second 2 (familiarized vs. unfamiliarized intact pairs) by 2 (familiarized vs. unfamiliarized rearranged pairs) repeated measures ANOVA was conducted for FC recognition response times. No main effects for intact pair familiarity ($F(1, 28) = 3.521$, $p = .071$, $\eta_p^2 = .112$) and rearranged pair familiarity ($F(1, 28) = .962$, $p = .335$, $\eta_p^2 = .033$) were found. The interaction between these variables was also not reliable ($F(1, 28) = .327$, $p = .572$, $\eta_p^2 = .012$). Familiarization of word pairs did not affect responses time for FC tests.

Discussion. Although the interaction showing a FC advantage for familiarized intact pairs was not significant, the general pattern of results show a trend similar to the results observed by Schliewinsky and Hockley (2016). The trends of the *d'* estimates of Experiment 3 provide some evidence for a FC discrimination advantage in a within design.

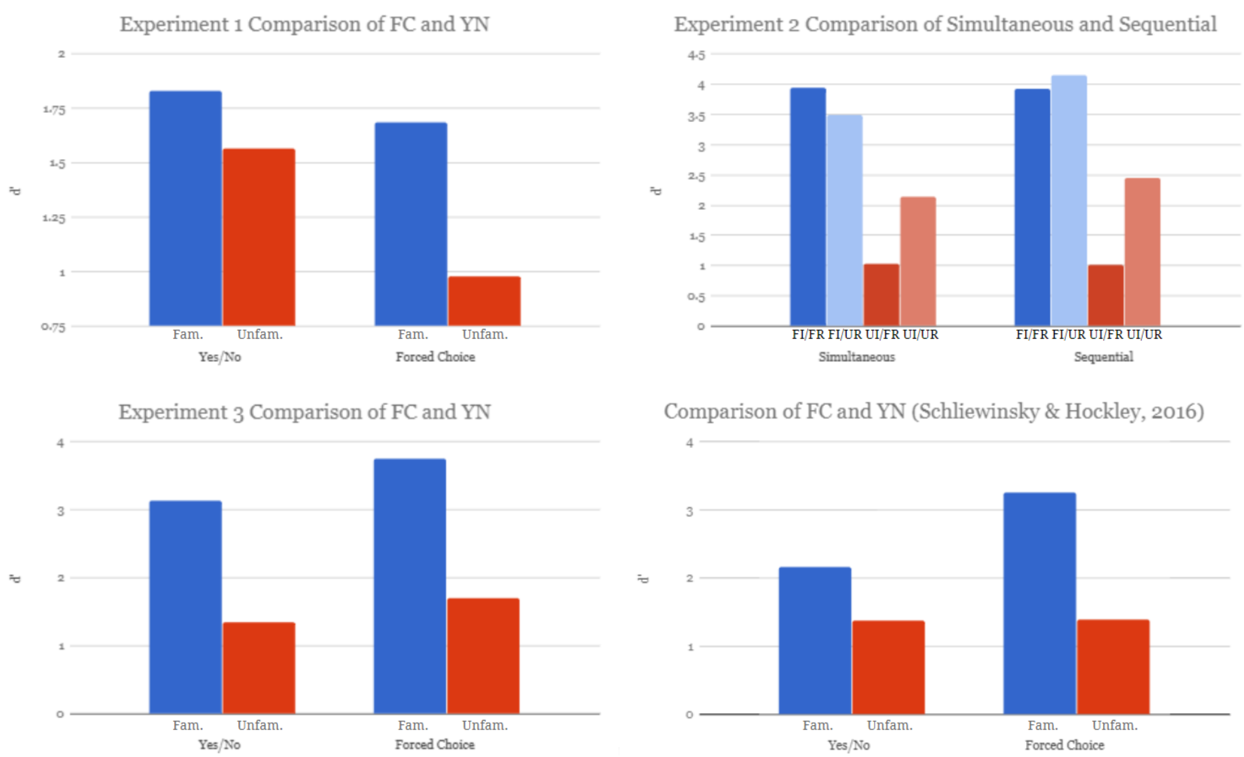
The failure to find a significant interaction could be due to certain factors and shortcomings of Experiment 3, mainly interference and lack of power due to the decrease in the number of FC trials. The interference could be due to the mix of different trial types. Rather than using one recognition strategy for a given recognition test in a between-subjects design (more recall-based recollection for YN recognition, and comparative familiarity for FC recognition), participants would have to switch strategies when recognition test type is compared within-subjects. The increased cognitive demands of switching recognition decision strategies may have attenuated the amount of strategy switching or may have led participants into adopting more similar or common strategies for the two types of recognition test trials. This would explain the lack of a significant difference in the *d'* values compared to Schliewinsky and Hockley (2016).

Power was also a potential issue for Experiment 3, as the number of FC trials were decreased compared to the other experiments conducted (4 of each type of FC test compared to 8). This was done to accommodate for the equal number of times word pairs appeared at test. This would also explain why there was no significant differences in the FC tests, and why there was no main effect of familiarity for rearranged pairs in Experiment 3 when these effects were observed in the FC tests of Experiment 2. Future studies should seek to compare FC and YN recognition discrimination with an increased number of tests per condition to remedy this power issue to verify if the discrimination advantage seen in Schliewinsky and Hockley (2016) can be found in a within-subjects comparison.

General Discussion

Figures 1 through 4 display the pattern of results for *d*' in Experiments 1 through 3 and Schliewinsky and Hockley (2016) for ease of comparison. It should be noted that the interaction comparing the *d*' results for FC and YN recognition tasks and the familiarized and unfamiliarized word pairs reached significance for Schliewinsky and Hockley (2016), but not for Experiments 1 through 3.

Figure 1. *The pattern of results for d' comparing FC and YN associative recognition tasks for (in order of left to right, top to bottom) (a) Experiment 1, (b) Experiment 2, (c) Experiment 3, (d) Schliewinsky & Hockley (2016).*



Note. (b) Familiarized Intact (FI), Unfamiliarized Intact (UI), Familiarized Rearranged (FR), and Unfamiliarized Intact (UI). (d) Adapted from Schliewinsky, G. R. & Hockley, W. E. (2016). "Differential Information Processing for Yes/No and Forced Choice Associative Recognition Tasks" (undergraduate thesis) by G. R. Schliewinsky and W. E. Hockley, 2016. Copyright 2016 by Wilfrid Laurier University. Adapted with permission.

The purpose of this study was to investigate how increased familiarity affects FC and YN associative recognition tasks and to build upon and replicate the FC discrimination advantage found by Ahmad and Hockley (2014), Ahmad, et al. (2015), and Schliewinsky and Hockley (2016). When only item familiarity was increased in Experiment 1, the effects of familiarity were greater in the FC than in the YN recognition test, although no overall significant advantage in discrimination was found for FC over YN recognition. There was no significant discrimination advantage between simultaneous and sequential FC tasks when pairs were familiarized in Experiment 2. As a within-subjects replication in Experiment 3, the same FC discrimination advantage over YN previously found by Schliewinsky & Hockley (2016) was not found. This is quite likely due to shortcomings of the experiment. Trends in the results suggest that increased word pair familiarity would result in some discrimination advantage for FC over YN recognition if it were not for the shortcomings.

Experiment 1 emphasized the importance of associative familiarity strength when making recognition decisions. Though familiarity of the individual items influenced responding, it did not lead to more accurate decisions. As Experiment 2 and 3 show, as well as Schliewinsky and Hockley (2016), familiarization of the associative information is necessary to increase the accuracy of associative recognition. There are several important implications of these findings. Increasing the familiarity of an item in the word pairs of Experiment 1 did not have a significant effect on the YN test, but it did have a significant effect on the intact pairs in the FC test. This result suggests that (a) item familiarity does affect associative recognition decisions even when item familiarity is not informative or diagnostic, and (b) the effects of familiarity appear to be greater for FC than YN recognition decisions. These effects may have even be greater if both words of the familiarized pairs had been familiarized instead of only one.

Experiment 2 compared simultaneous and sequential FC tasks with the increase of word pair familiarity. The results of Experiment 2 found no significant discrimination advantage for simultaneous versus sequential FC recognition for either familiarized or unfamiliarized word pairs. Proportion of correct responses and *d*’ analyses found effects and an interaction for both intact and rearranged pairs for across both sequential and simultaneous presentation formats, indicating that performance was best for trials with familiarized intact pairs and unfamiliarized rearranged pairs. Results of the simultaneous condition also provide a nice replication of the FC findings in Schliewinsky and Hockley (2016). The similar pattern of results where trials with familiarized intact pairs and unfamiliarized rearranged pairs were recognized best for both simultaneous and sequential FC suggests that participants are using a similar memory strategy. Many studies suggest that participants use a familiarity-based strategy in FC recognition (see Ahmad & Hockley, 2014; Ahmad et al., 2015; Bastin & Van der Linden 2003; Bayley, Wixted, Hopkins, & Squire, 2008; Khoe et al., 2000).

Experiment 3 was a replication of Schliewinsky and Hockley (2016), but as a within-subject design. YN and FC test trials were both presented at test. No significant discrimination advantage was found for FC over YN recognition previously found by Schliewinsky and Hockley (2016). It is reasonable to suggest that the failure of replication was due to shortcomings of the research, mainly interference and lack of power. Interference between the two test types could result in participants adopting a more common strategy, rather than relying on different ones for each task. Interference does suggest that this effect will be attenuated in within-subject designs compared to a between-subjects design used by Schliewinsky and Hockley (2016).

The reduction in the number of FC test trials to accommodate for an equal number of presentations of word pairs across the two types of tests resulted in a reduction in power. Trends of the results of this experiment are similar to other studies that have found this discrimination advantage of FC over YN recognition when familiarity of word pairs is increased (Ahmad & Hockley, 2014; Ahmad et al., 2015; Schliewinsky & Hockley, 2016). This similarity of the pattern of results suggest that the lack of this significant discrimination advantage was due to these shortcomings.

The CW pairs in Ahmad and Hockley (2014) and Ahmad et al., (2015) were unitized by the semantic information of the pairings. The increased pre-experimental exposure and experience with CW pairs increased their associative strength. The non-compound word pairs used in this experiment and Schliewinsky and Hockley (2016) relied more on episodic information about the pairs since participants made the associations within the study. The method by which participants created the associations (i.e., using the two words in sentences, or creating an interactive image of the two words) was not specifically instructed or controlled. Participants created the associative information based on the pairs rather than given a definition like Lloyd et al. (2015), or relied on pre-experimental familiarity of CW pairs like Ahmad and Hockley (2014). This accommodated for the varying information processing and encoding strategies used by the participants. That is, some participants may bind the word pairs better by visualizing the association as an image, while another participant may prefer to encode the two words in a sentence. Despite the differences of strategies to encode associations between two unrelated words, these studies share a similar pattern of results. Both pre-experimental and experimental influences of familiarity have a similar effect on associative recognition.

The influence of familiarity across the three experiments and Schliewinsky and Hockley (2016) provides some contradiction to the important assumption of signal detection theory that YN and FC test procedures measure associative recognition with equal sensitivity. Researchers should be cautious when using these paradigms, as evidence suggests a greater influence of familiarity in FC recognition over YN recognition when familiarity of word pairs is increased. Signal detection theory assumes that recognition decisions are based on one dimension of memory signal strength. For associative recognition, Hockley (1992) explains that the sum of the item and associative information are compared against a response criterion. If this sum of information is greater than the criterion, the participants will respond to a pair as old. If this information is less, they will respond to a pair as new. New responses are made when participants are not using the associative information, relying on item information, which is not informative in making accurate recognition decisions. Thus, participants must use the associative information to make a correct response. When the strength of the familiarity of the association is increased, this increases the likelihood of making a correct, old response to an intact pair. Schliewinsky and Hockley (2016) showed that when familiarity of word pairs was increased, *d*' estimates for FC was higher than for YN recognition, indicating a discrimination advantage. When familiarity of the word pairs is increased, the discrepancy between the distribution representing the old and new pairs in a FC recognition test is increased further than in an YN recognition test, moving the old distribution further from the criterion to respond. This represents the increased likelihood that the participants would discriminate an old intact pair from a new rearranged pair. This is shown by a greater *d'* value found in Schliewinsky and Hockley (2016). A similar trend in the results is seen in Experiment 3, where the discrepancy between *d*' values is greater for FC than in YN recognition.

Signal detection theory for item information functions along one dimension of signal strength of the items. For associative recognition, there is an influence of another dimension for the strength of the associations. Both the strength of the item and associative strength influence recognition performance. The difference is that the use of item information is not informative to making accurate decisions. This presents a problem when using models like signal detection theory for associative recognition, as this extra dimension of item information does not assist accurate performance (Experiment 1) and associative information does (Experiment 2 and 3) (Schliewinsky & Hockley, 2016). Additionally, the use of item and associative familiarity differentially affects YN and FC associative recognition, where FC recognition decisions are based more on familiarity. In which case, the one dimensional model cannot account for the evidence suggesting the influence of familiarity in associative recognition.

The trend of the greater discrepancy of the *d*' values for FC recognition over YN recognition in Experiment 3 and the discrimination advantage found by Schliewinsky and Hockley (2016) contributes to the dual-processing model of familiarity and recollection for associative recognition. Increasing the strength of the associations increases the ability to recall word pairings. To exemplify this, the familiarity causes participants to see pairing A-B to be more familiar than A-C. This in combination with the increased ability to recollect the exact pairing of A-B leads to more accurate responding. These two strategies are used differently for YN and FC recognition. Since YN decisions are based more on recollection, participants' ability to recollect A-B is influenced by the increased strength of the associations. That is, the strength of the memory of the associations is increased when word pairs were repeated, increasing both familiarity and recollection. Ahmad and Hockley (2017) state their findings of the CW effect for YN was due to a reliance of enhanced familiarity of the unitization of word pairs based on pre-experimental information. For FC recognition, the comparative strength based on familiarity of the pairs allows for correct recognition of intact pairs. This associative familiarity is enhanced by the familiarity of the repeated word pairs. This increase in familiarity ultimately influences both recollection and familiarity processing in FC and YN.

All three experiments of the present study provide evidence outlining the differences of YN and FC familiarity for associative recognition tasks, and suggest that researchers cannot assume the same recognition test procedures are equally sensitive measures for signal detection theory. Additionally, this research will allow for many future studies to investigate other factors and manipulations, such as familiarizing individual words and using both words in word pairs at study as initially intended for Experiment 1, or increasing the number of test trials in Experiment 3 to remedy the issue of power. Evidence from the present research and future studies could lead to creating a new model to account for the influence of familiarity in associative recognition.

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