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# The Effects of Associative Interference, Stimulus Type, and Item Familiarity on Associative Recognition Memory

Fahad Naveed Ahmad  
*Wilfrid Laurier University*

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The Effects of Associative Interference, Stimulus type, and Item familiarity on Associative  
Recognition Memory

by

Fahad Naveed Ahmad

Bachelor of Science (Honours), University of Toronto, 2008

THESIS

Submitted to the Department of Psychology

in partial fulfillment of the requirements for

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## Abstract

This study investigated whether recognition memory requires two retrieval processes (i.e., familiarity and recollection) as stated by the Dual process theory or requires one retrieval process (i.e., familiarity) as stated by the Single process theory. The first experiment investigated the effects of A-B, A-C, A-D, A-E interference on both word and picture pair recognition. As expected, it was found that a picture superiority effect was present in the baseline condition, but was reduced in the interference condition. Moreover, in the baseline condition, a non-mirror pattern (i.e., hits higher for picture pairs, but false alarm rates were the same) was present indicating picture pairs were encoded better than word pairs, however recall to reject strategy was the same. Furthermore, for both types of stimuli, false alarm rates and estimates of familiarity-based hit rates increased in the interference condition. The second experiment investigated if the effects of interference on false alarm rates occurred not due to the fan effect, but due to the familiarity of items in the overlapping pairs. Familiarity increased hit rates but did not affect false alarm rates for word pairs. Interestingly, familiarity had an effect on false alarm rates for picture pairs. In Experiment 3, a more extreme manipulation of item familiarity was used. Experiment 3 provided more conclusive findings than Experiment 2 supporting the theory that the effects of interference on hit rates and false alarm rates were determined by the familiarity of the individual items. Moreover, the results were in accordance with Kelley and Wixted's (2001) "some-or-none" model. Experiment 4 was similar in design and procedure as Experiment 1, however the two conditions were general and specific sentence conditions. The general sentence condition contained a general noun and specific location (i.e., the furniture is in the jungle). And the specific sentence condition contained a specific subject noun which was an instantiation of the general subject noun (i.e., the desk is in the jungle). Supporting the Dual process theory and similar to Experiment 1, there was a non-mirror pattern present in baseline condition. There were significantly higher hit rates present in the specific sentence condition than the general sentence condition. However, false alarm rates were the same for both sentence conditions. In addition, similar to Experiment 1, estimates of familiarity significantly increased in the interference condition for both types of stimuli. Overall, the results provide strong support for the theory that item familiarity eliminated the advantage in recognition performance for distinctive stimuli in associative recognition.

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## The effects of Associative Interference, Stimulus type and Item familiarity on Associative Recognition Memory

One of the common memory limitations people encounter is the failure to recognize objects, other people, pictures and word lists that they have encountered in the past. For example, you might see a person while shopping in the super market and may have a feeling of “knowing” the person. The person would seem familiar to you. Then the memory search process would begin trying to “recollect” the context in which you met the person. Episodic memory is defined as conscious memory for events that involves contextual details that accompany the event such as place and time (Tulving & Markowitsch, 1998, Tulving, 2002). Eventually the search may end up with the insight that the person is your neighbor Jane. However, the retrieval process may be further complicated if you had met people who had similar faces, names, or in similar contexts. Thus, if the retrieval cue elicits memory representations similar to the target, the similar memory representations act as competitors and interference would result. Interference is a generic term that describes the disruptive effects of irrelevant information and is characterized by slowed correct responding and reduced accuracy (Lustig & Hasher, 2001). Interference can be characterized by a difficulty in retrieving the target item due to similarity between the target item that is being searched for and other items in memory. This phenomenon is illustrated in the Fan effect (J. R. Anderson, 1974). That is, more associations with a single item make it harder to recall a specific association for that item (J. R. Anderson, 1974, J. R. Anderson, 1983).

There are, however, few studies that have investigated interference in episodic memory using the associative recognition paradigm. In an associative recognition (AR) task, participants study pairs of items rather than single items that are seen in an item recognition task. At test, associative recognition requires participants to discriminate between intact pairs (i.e., old or studied pairs) and rearranged pairs (i.e., new pairs) (e.g., Humphreys, 1978, Hockley & Consoli,

1999) A rearranged pair consists of one studied item of one pair and another studied item of another pair. Associative recognition is successful when intact pairs are endorsed (i.e., hits) and rearranged pairs are rejected (correct rejections). Associative recognition is unsuccessful when studied pairs are rejected (misses) and rearranged pairs are endorsed (false alarms). Thus, associative recognition performance improves as hit rates increase and false alarm rates decrease. Note also that memory for the individual items cannot assist associative recognition as both intact and rearranged pairs consist of old items. Discrimination is defined as an increasing function of the probability of correctly classifying a studied item (i.e., hit rate [HR]) and a decreasing function of probability of incorrectly classifying an unstudied item (i.e., false alarm rate [FAR]). An overall discriminability index can be defined by corrected recognition performance. Thus, associative recognition provides a relatively pure test of memory for relational information.

Two theories of recognition memory have been proposed to account for correct discrimination of intact pairs from rearranged pairs. These contrasting theories of recognition are characterized as single process based on signal detection theory (e.g., Gillund & Shiffrin, 1984, Hintzman, 1984, Murdock, 1982, Murdock, 1997, Humphreys, Bain & Pike, 1989, Criss & Shiffrin, 2004, Shiffrin & Steyvers, 1997, Hockley, 1992, Kelley & Wixted, 2001) and dual process theories based on lesion studies of amnesics (Yonelinas, 1994, Yonelinas, Dobbins, Szymanski, Dahliwal & King, 1996, Yonelinas, 2002, Malmberg & Xu, 2007, Xu & Malmberg, 2007). Importantly, experimental manipulations such as pair repetition, type of stimulus, list strength, study time and word frequency have been implemented to provide validity to the predictions of these single process and dual process theories.

## Dual process theory of Associative recognition

According to Dual-process theories, both familiarity and recollection work together to aid in associative recognition. Recollection is typically described as a search for specific information and retrieves episodic or associative details. It is a process similar to that involved in a recall task. In contrast, familiarity provides non-specific information about past events (Verde, 2004). A retrieval cue matches each item in memory to some degree on the basis of similarity or learned associations, and the global or aggregate match is represented psychologically as a unidimensional sense of familiarity strength (Verde, 2004). However, whether recollection is high threshold or all-or-none or graded, is not established among dual process theorists. Two prominent Dual process theories are that of Yonelinas (1994) and Malmberg & Xu (2007). According to Yonelinas's (1994) dual process model called the dual-process signal-detection/high-threshold theory (i.e. DPSD), familiarity reflects the assessment of "quantitative" memory strength information in a manner similar to what is described by signal detection theory. According to the signal detection model, items can be placed on a familiarity continuum, where new items fall on the low end of a continuum and old items fall on the high end of a continuum. In the signal detection model, there is no threshold on which to be certain that the item was familiar, since the familiarity of old and new items overlap (Yonelinas, Dobbins, Szymanski, Dahliwal & King, 1996). In contrast, recollection reflects a threshold retrieval process whereby "qualitative" information about a previous event is retrieved (Yonelinas, 2002). That is, participants may be able to retrieve aspects of study event such as spatial context, however for other items they are unable to retrieve any accurate qualitative information (i.e., other items fall below the recollective threshold) (Yonelinas, 2002).

In contrast, according to Malmberg & Xu's (2007) Retrieving Effectively from Memory (REM) dual process theory, both familiarity and recollection contribute to associative recognition. The decision-making steps of the model are the following: Memory is probed with a compound cue and the subjective criterion is compared with the familiarity of the test pair. If the criterion is not exceeded, then the response is negative. If the criterion is exceeded by the familiarity of the test pair and episodic details are able to be retrieved by the sampling and recovering, those details are compared with the stimulus. The response is positive, if the details match the stimulus. The response is negative, if the details do not match the stimulus. The subject guesses with less success in guessing positively if the sampling and recovery processes are unsuccessful (Malmberg, Holden, & Shiffrin, 2004). Familiarity is enough to recognize intact pairs as quantified by hits. However, for correct rejection of rearranged pairs, recollection must oppose the familiarity of the individual items (i.e., recall to reject) as quantified by false alarms. In other words, the participant must recall or recollect the original associate of one of the items (i.e., relational information) in order to reject the rearranged lures.

For a compelling test of the dual process theory, the associative recognition paradigm is supplemented by remember-know judgments as a way to separately measure recollection and familiarity (Verde, 2004). According to the remember-know paradigm, participants indicate whether they remember specific details about the past encounter, or simply know in the absence of such detail that the word was old or familiar. Remembering and recollection are associated with specific information, whereas knowing and familiarity are associated with a nonspecific sense of past experience.

In the remember-know procedure, recollection is measured by the proportion of remember responses. There has been some debate, however, concerning how to measure

familiarity As participants are typically asked to qualify an old response as either based on recollection (remember) or familiarity (know), the proportion of know responses are constrained by the proportion of remember responses Yonelinas (2002) has suggested recollection and familiarity are independent, and thus the proportion of know responses can be calculated independently of the proportion of remember responses independent remember know (IRK) = the proportion of know responses divided by one minus the proportion of remember responses [know/ (1-remember)]

### Single process theory of Associative recognition

In contrast to dual process theories, for Single process theories, only familiarity strength is considered necessary for recognition memory According to Single-process familiarity-based theories, the basis for the recognition decision is a continuous random variable referred to as familiarity Single-process familiarity-based theories are based on the signal detection model, which was discussed earlier By setting some level of familiarity as a response criterion and accepting items that exceed this criterion as having been studied, memory judgments are made (Yonelinas, 1997) In general, according to all single process theories, studied items are recognized accurately not because they can be recollected but due to the studied items being sufficiently familiar

There are various single process familiarity-type theories but the most prominent is the independent cue model which has two versions Independent cue models assume that the pairwise associations of two items are represented separately from the items themselves (Xu & Malmberg, 2007) When a test pair is presented, the pairwise association is created anew and used to probe memory One version of the independent cue model assumes that the probe involves only comparing the independent cue with the contents of memory (Murdock, 1982) For

the recognition decision, the items making up a pair do not play a role in the recognition decision. Intact pairs tend to be more familiar than rearranged pairs, because an intact pair is represented in memory but a rearranged pair is not (i.e., matches contents of memory only randomly). Murdock (1982) TODAM model shares similarities with the SAM model (Gillund & Shiffrin, 1984), the Minerva II model (Hintzman, 1982), the Matrix model (Humphreys, Bain, & Pike, 1989). In general, all these global matching models along with the TODAM model propose that a global matching operation underlies single item and pair recognition, whereas a retrieval operation underlies recall. However, the models differ in whether matching occurs with individual memories, so that the strength of individual matches must be summed to produce the overall matching strength (the global match). In the Matrix and TODAM models, the match is with the composite memory, since the individual memories are superimposed. Moreover, at test no separate summation process is required (Dyde et al., 1990). The models also differ in terms of type of information retrieved during recall. There is agreement that recall requires the recovery of information that particularly identifies a particular response. This is an individual memory in SAM and MINERVA II models, and in the Matrix and TODAM models this is a vector of feature information that specifies a word in the subjects' "lexicon".

Wixted and Mickes (2010) present a combined dual-process/single process account of associative recognition in their continuous dual process model (see also the "Some or None model" of Kelley & Wixted, 2001). This view of associative recognition decisions are based on a memory strength dimension that represents the combination of familiarity and recollection. Unlike other dual-process views, Kelley and Wixted (2001) assume that both familiarity and recollection are graded dimensions. They also assume that the remember-know response

procedure is not a pure measure of recollection, as remember judgments are assumed to be based on overall memory strength which is a combination of familiarity and recollection in this model

### Using associative interference as a test of Single and Dual process theories

There are a variety of behavioural methods to test which theory of associative recognition memory is correct. One manipulation, some researchers have employed is the introduction of interference (i.e., overlapping pairs) in studied pairs. Interference can be introduced in the associative recognition paradigm by manipulating the similarity of items. Overlapping pairs (house-car, house-plane) are more similar to one another than non-overlapping pairs (cat-apron, chair-tent). In general, both single and dual process theorists agree that interference would increase item familiarity strength and affect recognition performance in terms of increasing hit rate and false alarm rate.

Single process theory would predict that both hit rates and false alarm rates would increase because of the increase in item familiarity. However, according to single process theory even though interference would increase hit rates and increase false alarm rates, the discriminability (i.e., hit rates minus false alarm rates) would not change. In two experiments, Dyne, Humphreys, Bain and Pike (1990) have demonstrated these effects supporting the single process theory. Dyne and colleagues (1990) introduced words that were present more than in one pair (i.e., AB, AC, EH, and EI) and at test would present the intact and rearranged word pair. When examining the effects of interference on associative recognition in two experiments involving random word pairs, Dyne and colleagues (1990) found both the hit rate and false alarm rate increased slightly but not significantly under interference conditions. Moreover, in contrast to a cued recall condition there was no sign of associative interference in recognition. However, from the experiments, Dyne and colleagues (1990) found that discriminability did not change.



due to interference. In fact, Dyne and colleagues (1990) state in the general discussion of their study that the overall mean from the series of experiments that they conducted was a better estimate of the effect of interference on associative recognition. Thus, the overall effect of interference on the hit minus false alarm rate was close to zero in the Dyne et al. (1990) study, providing strong support for the single process theory. Similarly, dual process theory would also predict that hit rates would increase because of item familiarity leading to high familiarity strength. However, in contrast to single process theory, false alarm rates would increase because interference would reduce the effectiveness of recollection. Thus, in the interference condition, the individual would rely more on familiarity than recollection for correct rejection of rearranged pairs. According to dual process theorists, the reduced effectiveness of recollection for recognition due to interference should be seen in the participants' remember and know responses. According to the dual process theory, in the interference condition, remember hit rates should decrease whereas IRK hits would increase. Moreover, remember false alarms should decrease and IRK false alarms should increase with interference. Indeed, through three experiments Verde (2004) demonstrated these effects supporting the dual process theory. Finally, unlike Dyne and colleagues (1990), Verde (2004) found a significant decrease in discrimination with interference.

Therefore, single process and dual process theories make the same general predictions regarding the effects of interference on associative recognition even though single process theorists do not consider recollection to be a separate basis of recognition. However, they differ on predictions of the effects of interference on overall discrimination. Moreover, dual process theories support the reduction of recollection with interference by correspondence to remember and know judgments.

Verde (2004) demonstrated that associative recognition can be affected significantly by interference in three experiments and suggested the findings supported the predictions of the dual-process model. In Verde's (2004) study, associative interference was created in recognition by the introduction of overlapping paired associates (e.g., A-E, A-F, B-E, B-F). In the interference condition, words appeared in more than one pair (e.g., the study pair AE or BF). In Verde's (2004) first experiment, where words were encoded in meaningful sentences, associative interference resulted in a significant decrease in recognition hits and an increase in false alarms. However, in the third experiment, where random noun pairs were studied, increasing levels of associative interference resulted in an increase in recognition hits, and a similar increase in false alarms. For both experiments, remember hits always decreased and know hits always increased with the degree of interference, reflecting the effects of interference on recollection and familiarity processes (Verde, 2004). Furthermore, only know false alarms increased with interference. Thus, the interference condition reduced the likelihood of recollecting old items but increased their familiarity strength. As predicted from the dual process account, interference increased the false alarm rate, because familiarity strength was increased for old items, but chance of recollection was reduced. With the introduction of interference, familiarity strength rather than recollection contributed to recognition performance. Thus, random noun pairs led to greater recognition hits than sentences because recollection is more difficult for noun pairs, so participants relied more on familiarity of items and associations. To explain this difference, Verde (2004) suggested that sentences being a more meaningful form of encoding, lead participants to use more recollection than familiarity at retrieval. However, it should be noted that Verde (2004) did not use a baseline condition in this third experiment, which makes it difficult to interpret the results of his third experiment. Verde (2004) suggested the significant

effects of associative interference on associative recognition supported the dual process model based on remember/know results

Thus, the important question arises, why did Verde (2004) find that associative interference significantly affected associative recognition whereas Dyne and colleagues (1990) found a marginal increase in hit rates and false alarm rates with interference? In fact, Dyne et al (1990) found that interference only affected cued recall but not associative recognition. Firstly, study instructions used in Dyne et al (1990) study were different from Verde's (2004) study. Moreover, the type of encoding varied for baseline and interference word pairs. In Dyne and colleagues (1990) first experiment, participants rated word pairs during the study phase on level of similarity for the baseline condition, whereas the overlapping word pairs were rated in terms of imaginability. For example, a word pair (i.e., AB) would be presented in the similar condition, whereas the overlapping word pair (i.e., AC) would be presented in the imaginability condition. Thus, in Experiment 1, overlapping pairs underwent a deeper form of encoding than non-overlapping pairs. However, in Dyne et al's (1990) second experiment, word pairs in the baseline condition were rated in terms of sentence judgment, whereas the overlapping word pairs were rated in terms of similarity. In contrast in all experiments of Verde's (2004) study, participants were presented with pairs and were instructed to study them for a later recognition test. No encoding instructions were provided in terms of what method to use for encoding.

Secondly, the level of interference in Dyne and colleagues (1990) study was low for examining effects on associative recognition. Whereas, Dyne et al (1990) had a word repeated in a word pair only twice (i.e. A-C, A-D), Verde (2004) in Experiment 3 had a word repeated in a word pair either twice or three times or four times. Indeed, Verde (2004) found as the level of interference increased, there was a significant effect of interference on associative recognition. In

Verde's (2004) first experiment, the word was repeated in word pairs encoded in a sentence four times. In Verde's (2004) third experiment, the word was repeated in word pair either two times, three times or four times. Interestingly, similar to Dyne et al (1990), Verde (2004) found a trend towards significance for the effects of low levels interference (i.e., repeated in a word pair twice) on associative recognition.

Therefore, there are a number of reasons why Verde (2004) found a significant effect of interference on associative recognition whereas Dyne and colleagues (1990) did not. Firstly, Verde (2004) did not use different encoding instructions for interference pairs. Secondly, in Verde's (2004) study, participants were just told to study the pairs for a later memory test. Thirdly, Verde (2004) found a significant effect of interference with words that were repeated in four pairs rather than repeated twice. It can also be suggested based on both Dyne et al, (1990) and Verde (2004) cued recall is more susceptible to interference than associative recognition.

#### The effects of stimuli type on associative recognition as support for the Dual process theory

Support for the dual process theory can be also obtained from Hockley's (2008) study. Hockley (2008) demonstrated a picture superiority effect in associative recognition task in a comparison of random picture pairs (line drawings of objects) and random concrete word pairs (the verbal labels of the line drawings). That is, the picture pairs were recognized better (i.e., higher hit rates) than word pairs. Thus, picture presentations resulted in better encoding of both item and associative information (Hockley, 2008). Deeper, more extensive conceptual processing of the picture pairs would benefit both memory for the individual items and the formation of memorable associations between the items. This type of encoding would explain why picture pairs are more distinctive than word pairs. Interestingly, there was no difference in the false alarm rates of picture versus word pairs. That is, there was a non-mirror pattern in the picture

superiority effect. Thus, a mirror pattern (Joordens & Hockley, 2000) was not seen in the picture superiority effect for associative recognition in Hockley's (2008) study that is typically present in the picture superiority effect for item recognition (Paivio, 1976, Nelson, Reed & Walling, 1976).

According to Hockley (2008), the results also support the dual process theory of associative recognition (Xu & Malmberg, 2007), if it is assumed that the picture pairs are better encoded than word pairs but the effectiveness of the recall-to-reject strategy is similar for both types of pairs. Hockley (2008) suggested similarity in recall-to-reject strategy for picture pairs and word pairs follows from Kelly and Wixted (2001) proposed "some-or-none" model of associative recognition and the dual process model proposed by Xu and Malmberg (2007). According to Kelly and Wixted (2001) based on their study of effects of repetition of several word pairs on associative recognition, participants rely on both item information and retrieval of relational information to make associative recognition decisions. Strengthening pairs increases the familiarity of the individual items and also increases the likelihood of retrieving the original studied pairs. These factors work together to increase the hit rate for intact pairs, but work in opposition to each other for rearranged pairs. Thus, the "some-or-none" model predicts no differences in the false alarm rates for strong and weak rearranged pairs when two opposing factors serve to offset or cancel each other.

Similarly, picture pairs strengthen the encoding of both item and associative information and so the non-mirror pattern in the picture superiority effect can be explained in same manner as was Kelley and Wixted's account of the effects of repetition on pair recognition. That is, the opposing forces (i.e., familiarity vs. recall) were approximately equal and cancelled out. Thus, in order for a mirror pattern to be present in the picture superiority effect, the contribution of

recollection must be significantly greater than that of item familiarity. The non-mirror pattern demonstrated in Hockley (2008) study can also be explained by Xu and Malmberg's (2007) dual-process model. Hit rates are higher for picture pairs than word pairs, because the familiarity value is higher for picture pairs since picture pairs are better encoded than words in terms of item familiarity and associative information. However, there should be similar mean incorrect responses (i.e. false alarms) for rearranged word pairs and rearranged picture pairs, because the response is "new" if the details do not match the probe (i.e. recall-to-reject) is similar.

However, the non-mirror pattern in the picture superiority effect cannot be supported by the single process theory, because single process theories assume that item and associative information are combined in the information retrieved in response to the cue (Clark & Gronlund, 1996, Hockley, 1992). Thus, single process theories would incorrectly predict that false alarm rates for picture pairs or strong pairs would be higher than word pairs or weak pairs.

The important question arises, would there be differential effects of interference on associative recognition of word pairs and picture pairs? It is expected that picture pairs would have marginally higher hit rates than word pairs in the interference condition, since only item familiarity would be increased in the interference condition. Moreover, pictures undergo deeper semantic processing than words. However, the recall to reject strategy would remain the same for word pairs and picture pairs in the interference condition, because familiarity and recollection cancel each other (Kelley & Wixted, 2001) out or the recall-to reject strategy is the same (Xu & Malmberg, 2007).

In terms of remember and IRK responses, IRK hit rates would be significantly higher than remember hit rates. Moreover, IRK and remember false alarms would increase with interference. This would support the theory that one has to rely more on familiarity when

recollection is reduced to interference. This question was addressed in Experiment 1 of the present study.

### The effects of Item familiarity on associative recognition as support for Dual process theory

The effects of associative interference on associative recognition as demonstrated by increased false alarm rates (Verde, 2004), may be due not only to the inability to recollect specific pairings but also due to an increase in familiarity strength of individual words in the word pairs. That is, an increase in item familiarity increases false alarm rates. Since, individual words in overlapping pairs are repeated, it is possible the familiarity strength of individual words may also lead to increased false alarm rates during associative recognition. That is, studying A with B and C will increase difficulty of retrieving individual associations, but also repetition of single words or items will increase item familiarity. However, whether item familiarity has similar effects on item recognition and associative recognition is debatable.

Verde (2004, Exp 3) investigated the effects of interference on word pair recognition by repeating items in overlapping pairs. Similar to Greene (1999), Verde (2004) found, that repeating individual words in different word pairs (i.e., A-B, A-C) resulted in a significant increase in both the false alarm and hit rates of associative recognition decisions.

The findings by Green (1999) and Verde (2004), however, contrast with recent studies of associative recognition investigating the effects of increasing the familiarity of items and associations by repeating studied pairs (Cleary, Curran & Greene, 2001, Kelley & Wixted, 2001, Verde & Rotello, 2004). For example, Kelley and Wixted (2001) investigated the effect of repeated versus non-repeated word pairs on associative recognition. It was found that the strengthening manipulation had a large effect on the hit rate for intact pairs but no significant effect on the false alarm rate for rearranged pairs. That is, the hit rate for intact pairs in the

repeated pair condition was significantly higher than that of the non-repeated pair condition. However, the false alarm rate for rearranged pairs composed of items from strong or weak study pairs did not differ. Kelley and Wixted (2001) concluded that the false alarm rate for rearranged pairs of repeated and non-repeated pairs were equal because the opposing forces of item familiarity and recollection of the study associations were approximately equal and cancelled each other out. In contrast, for the intact pairs familiarity and recollection worked together, so hit rate increased in the repeated pair condition. Furthermore, in a study involving only overlapping word pairs, Verde and Rotello (2004) found hit rates were greatest for the strong condition, followed by baseline, and lowest in the weak condition. Interestingly, false alarm rates were similar for baseline, weak and strong conditions. Verde and Rotello (2004) concluded this finding supported Kelley and Wixted's (2001) conclusion that increased familiarity of individual items of stronger pairs is cancelled out by increased recall-to-reject for rearranged pairs made up of stronger items.

Thus, the question arises if item familiarity was manipulated to a greater degree than associative information, would false alarm rates not be higher in the familiar condition for associative recognition as in accordance with Kelley and Wixted's (2001) "some-or none model"? This question was addressed in Experiments 2 and 3 of the present study.

#### The effects of encoding word pairs in sentences on associative recognition memory

Finally, in Verde's (2004) first experiment, specific words (i.e., a profession and a location) were encoded in sentences (ex "The doctor is in the garage"). Interference in the first experiment involved pairing four person nouns denoting professions and four locations in all possible combinations to yield 16 unique sentences. It was found that the associative recognition hit rate decreased whereas the false alarm rate increased with interference. This finding



contrasted with that of the third experiment where there was an increase in hit rate and false alarm rate for word pairs involving a similar level of interference. Verde (2004) suggested that these findings supported the dual process account, since differences in materials or tasks may lead to differences in the relative contribution of recollection and familiarity. That is, sentences may lead to a greater role of recollection than familiarity during the retrieval process, due to deeper semantic encoding for intact pairs. However, under interference conditions it is familiarity that determines increases or decreases in hit rate (Verde, 2004). In support, Verde (2004) found that with interference, the remember hit rate decreased whereas IRK hit rate increased in the interference condition. There was also an increase in IRK false alarm rate due to an increase in familiarity strength. The remember false alarm rate also increased with interference due to participants claiming recollection for rearranged pairs because of high similarity of those pairs to memories of studied pairs or studied items (i.e., the fan effect).

In Verde's (2004) first experiment, the nouns in each sentence were specific (e.g., the doctor) rather than general (e.g., the man). How would interference affect the recognition of nouns encoded in terms of a general versus a specific instantiation of their meaning? Certainly, specific nouns are recognized significantly better than general nouns at test. Specific nouns may also share similarities with the encoding of pictures since both may involve deeper and more elaborate semantic processing, whereas the encoding of general nouns in sentences or individually may be a more shallow and less elaborate level of processing. A study by Anderson, Pichert, Goetz, Schallert, Stevens & Trollip (1976) found that a particular term naming the expected instantiation (i.e., specific term) of a general term was a better cue for the recall of a sentence than the general term itself, even though the general term had appeared in the sentence and the particular term had not. For example, for the sentence, 'the man planned the house', the

particular noun, architect, would be a better cue for recall of the sentence than the general noun, man. In their experiment, participants would study one of two types of sentence: a target sentence or a control sentence. The target sentence would lead the participant to encode the general term as a specific term. All the nouns were general, they were either encoded in a general sense, or in a specific sense based on the sentence context. For example, 'the fish attacked the swimmer' would lead to encoding of "fish" in terms of "shark". In contrast, the control sentence (e.g., 'the fish avoided the swimmer') would not lead the participant to encode the general term as a specific term. At test, participants were given a particular cue or general cue for the two types of sentences. It was theorized by Anderson and colleagues (1976) that people select from among the indefinitely many meanings a term can have, a sense which permits a coherent overall interpretation of the message. Therefore, associative interference should have a different effect on nouns encoded in a general versus a specific manner. Items encoded in a specific sense should suffer less interference than items encoded in a general sense because they will share less similarity with interfering items. This question was addressed in Experiment 4.

### **Overview of Experiments**

Four experiments were conducted to further examine the effects of interference, familiarity, and type of stimuli on associative recognition to test the dual process account of associative recognition memory. The goal of Experiment 1 was to determine whether associative recognition for picture pairs was less susceptible to interference than word pairs. The aim of Experiments 2 and 3 was to investigate the extent of contribution of item familiarity to the effects of interference. That is, if the effect of interference on associative recognition is determined by the strength of familiarity of the individual items within the pairs and not just due to the associations between items. The goal of Experiment 4 was to compare the effects of

interference on associative recognition for general and specific instantiations of noun-location pairs that were encoded and tested in sentences

### **Experiment 1**

The goals of Experiment 1 were to replicate Verde's (2004) interference effect for word pairs, and see if a similar effect was obtained for picture pairs. It was predicted that a picture superiority effect would be present in the baseline condition and performance for both word and picture pairs would decrease with interference, but still be better for pictures than words. There would be a significantly higher hit rate for picture pairs than word pairs in the baseline condition, because picture pairs are encoded more deeply than word pairs in terms of both item and associative information (Hockley, 2008). Individual pictures and the associations formed between them benefit from deeper or more conceptual levels of processing (Weldon & Roediger, 1987, Weldon et al., 1989). Deeper, more extensive conceptual processing of the picture pairs would benefit both memory for the individual items and the formation of memorable associations between the items.

Moreover, hit rates would significantly increase in the interference condition but picture pairs would have a slightly greater hit rate than word pairs in the interference condition because of the greater role of item familiarity. That is, in the interference condition, only item familiarity would be aiding in correct recognition of word or picture pairs.

In terms of false alarm rates in the base line condition, it was predicted that false alarm rates would be the same for picture pairs and word pairs since Hockley (2008) demonstrated that the picture superiority effect is represented as a non-mirror pattern. The reason being, pictures are better encoded than words, but the recall-to reject strategy is similar for both types of pairs.

supporting Kelley & Wixted (2001) 'some or none' process model and Ken and Malmberg's (2007) dual process model

However, it was predicted that false alarm rates would increase in a similar pattern for both word pairs and picture pairs in the interference condition. The reason being, the recall-to-reject strategy would be less effective in the interference condition for both word and picture pairs. Furthermore, the recall-to-reject strategy is the same for picture pairs and word pairs. If picture pairs are simply stronger associations than word pairs as Hockley (2008) argued, then we should see the same pattern of effects of interference for picture pairs as word pairs. Essentially, item familiarity would play a significantly larger role than recollection of the associated item in recognition accuracy by increasing hit rates and false alarm rates in the interference condition. False alarm rates would be higher in the interference condition because recollection would be ineffective in retrieval due to the fan effect and item familiarity would not be helpful.

The pattern of results predicted for old responses would be supported by the results of the remember and know procedure. It was predicted that IRK hit and false alarm rates would increase in the interference condition for both word and picture pairs. However, remember hit rates would decrease and remember false alarm rates would increase in the interference condition for both word and picture pairs. This pattern of remember and IRK responses was predicted because familiarity strength increases with interference, whereas the effectiveness of recollection (i.e., recall-to-reject strategy) decreases with interference.

## **Method**

*Participants* All participants in each study were undergraduate students enrolled in an undergraduate psychology course in Wilfrid Laurier University who participated for course credit. A total of 60 students participated in Experiment 1. Nine participant data files were not

included in the analyses because of chance performance in the baseline conditions (i.e., their hit rates were equal to or less than their false alarm rates). Thus, a total of 51 participants took part in the study with 27 participants in the word pair condition and 24 participants in the picture pair condition.

*Materials and Apparatus* The experiment was run on PC compatible laboratory computers equipped with 17" LCD monitors. Super Lab software (Cedrus corp.) was used to control stimulus presentation and response recording. The stimuli consisted of 200 black-and-white line drawings of objects chosen from the Snodgrass and Vanderart (1980) and Bonin, Peereman, Malardier, Meot, and Chalard (2003) collections. Care was taken to select pictures that were both different from each other and easily identifiable with a single verbal name or label (e.g., candle, book, cake). A random half of the selected items were used as pictures, and the verbal labels of the other were used as words. The pictures and words of each pair were presented against a white background.

*Procedure* The study list consisted of a total of eighty words or eighty pictures. There were 64 word pairs or 64 picture pairs. There were two conditions in the study phase. In the baseline condition, there were no overlapping pairs yielding 16 word pairs comprising 32 words. That is, words in pairs were only presented once. In the interference condition, four words were assigned the left position, four words were assigned the right position, and possible combinations of left and right position yielded 16 unique pairs made up of eight words (each word will appear in 4 pairs). The pairing of words in the interference condition looked like this: A-E, A-F, A-G, A-H, B-E, B-F, B-G, B-H, C-E, G-F, C-G, C-H, D-E, D-F, D-G, D-H.

The first and last four pairs of the study list in the baseline condition acted to buffer primacy and recency effects. The test list consisted of 128 word pairs or 128 picture pairs. 64

studied pairs and 64 rearranged pairs. Refer to Table 1 for a depiction of the experimental design. Table 1 shows how retrieval processes can be described in terms of the degree of match between a retrieval cue and representations in memory. For example, if an individual studied a list of six word pairs: axe-box, axe-hat, axe-hammer, axe-umbrella, bottle-helicopter, bottle-kite and so on. There are three possible degrees of match between a word pair or picture pair presented as a test probe or item in memory. The order of pairs in the study and test lists was presented in a random order. The order was not the same for each participant.

Prior to the beginning of the experiment, participants were randomly assigned to either the word pair or picture pair condition. The 35-min session consisted of a study phase, and a test phase. Before the study phase began, the participants were instructed to learn the word or picture pairs for a memory test to follow. The participants were given the following instructions: "Try to associate each pair of words [or pictures] so that you will remember which words [or pictures] were shown together." During the study phase, each word pair or picture pair appeared in the center of the screen for 4,000 msec.

After the study phase was completed, for approximately one minute duration, the experimenter briefly provided instructions to the participant regarding the test phase in terms of old and new judgments and the use of remember and know judgments. Remember-know instructions were adapted from standard ones used by Gardiner, Ramponi, and Richardson-Klavehn (1998). To summarize, the participants were told that remembering is the ability to consciously bring back details of the study episode, such as where in the study list an item had appeared or what images or associations it had invoked at the time, and that knowing is a sense of familiarity in the absence of such detail. During the test phase, each trial began with a fixation line of "+" symbols displayed in the center of the screen for 1,000 msec. A test word pair or

picture pair replaced the fixation line and remained until the participant responded. For each word pair or picture pair presented at test, the participant had four choices for key presses. The “z” key was pressed for new, familiar judgments. The “c” key was pressed for new, remember judgments, the “,” key was for old, familiar judgments, and the “/” key for old, remember judgments.

*Design* The experiment was a 2 (stimuli: words vs. pictures) X 2 (condition: baseline vs. interference) X 2 (test probe: intact vs. rearranged) mixed analysis of variance (ANOVA) design. Stimuli was the only between-participants variable. The dependent variables were recognition accuracy and remember/know responses.

## **Results**

The proportion of hits (correct old responses to intact pairs) and false alarms (incorrect old responses to rearranged test pairs) for the word and picture pairs in both the baseline and interference conditions are presented in Table 2. The .05 level of significance was used to evaluate all statistical outcomes.

### *Analyses of Recognition responses*

A 2 (Stimuli: word vs. picture pairs) X 2 (Condition: Baseline vs. Interference) X 2 (Probe: Intact vs. Rearranged) mixed factor analysis of variance (ANOVA) was conducted on the proportions of old recognition responses collapsed over remember and know responses. There was a significant main effect of test probe [ $F(1, 49) = 112.050, MSe = 4.620, p < .001$ ]. The hit rate was significantly higher than the false alarm rate showing that overall discrimination performance was above chance. There was also a significant main effect for condition [ $F(1, 49) = 93.766, MSe = 3.047, p < .001$ ], indicating overall old responses were reliably higher in the interference than in the baseline condition. The main effect for stimuli was not significant [ $F(1,$

49) = 1.416,  $MSe = 0.58$ ,  $p = .240$ ] That is, overall old responses did not differ between word and picture pairs

The interactions between probe and stimuli [ $F(1, 49) = 3.219$ ,  $MSe = 1.33$ ,  $p = .079$ ], condition and stimuli [ $F(1, 49) = .973$ ,  $MSe = 0.32$ ,  $p = .329$ ], and the interaction between all three factors [ $F(1, 49) = .423$ ,  $MSe = .008$ ,  $p = .518$ ], were not significant. The main effects of probe and condition, however, were qualified by a significant probe by condition interaction [ $F(1, 49) = 54.706$ ,  $MSe = 1.037$ ,  $p < .001$ ]. This interaction shows that there was a greater difference between hit rates and false alarm rates in the baseline condition than in the interference condition for both word and picture pairs. Moreover, this shows that overall discrimination was greater in the baseline than in the interference condition.

Paired sample t-tests indicated that in terms of hit rates for word pairs, the interference condition produced a reliable increase in recognition hits over the baseline condition [ $t(26) = 3.190$ ,  $p = .004$ ,  $p < .05$ ], whereas for picture pairs, the interference condition did not produce a significant increase in recognition hits [ $t(23) = 1.733$ ,  $p = .096$ ]. Moreover, paired sample t-tests indicated that in terms of false alarms for word pairs, the interference condition produced a reliable increase in recognition false alarms [ $t(26) = 8.274$ ,  $p < .001$ ]. Similarly, paired sample t-tests indicated that in terms of false alarms for picture pairs, the interference condition produced a reliable increase in recognition false alarms [ $t(23) = 7.749$ ,  $p < .001$ ].

The interaction between test probe and stimuli, although not reliable, did approach significance. Independent sample two-tailed t-tests confirmed that the hit rate was greater for picture pairs than for word pairs only in the baseline condition [ $t(49) = 2.609$ ,  $p < .05$ ], whereas there was no difference in false alarm rates in the baseline condition between picture pairs and word pairs [ $t(49) = .121$ ,  $p = .904$ ]. These results replicate the picture superiority effect for



associative recognition observed by Hockley (2008) in the baseline condition. In contrast, there was no difference in hit rates in the interference condition between word and picture pairs [ $t(49) = 4.50, p = .000$ ] and no difference in false alarm rates in the interference condition between word and picture pairs [ $t(49) = -0.986, p = .328$ ].

#### *Analyses of Remember responses*

The mean proportions of remember responses in each stimulus and interference condition are also presented in Table 2. A 2 (Stimuli: word vs. picture pairs) X 2 (Condition: Baseline vs. Interference) X 2 (Probe: Intact vs. Rearranged) ANOVA was conducted on these proportions. There was a significant main effect of test probe [ $F(1, 49) = 33.913, MSe = 2.538, p < .001$ ] indicating the overall remember hit rate was greater than the overall remember false alarm rate, showing that the discrimination of remember responses was greater than chance. The main effect of stimuli was not significant [ $F(1, 49) = 0.003, MSe = 0.000, p = .955$ ]. Overall remember responses did not differ between word and picture pairs. However, there was a significant main effect for condition [ $F(1, 49) = 19.139, MSe = 0.444, p < .001$ ] indicating overall old remember responses were reliably higher in the interference condition than in the baseline condition.

The interaction between stimuli, condition and probe was not significant [ $F(1, 49) = 1.467, MSe = 0.022, p = .232$ ]. Moreover, the stimuli and test probe interaction was not significant [ $F(1, 49) = 0.742, MSe = 0.056, p = .393$ ]. However, the main effects of condition and probe were qualified by a significant condition by probe interaction [ $F(1, 49) = 35.144, MSe = 0.516, p < .001$ ]. This interaction showed there was a significantly greater difference between remember hit rates and remember false alarm rates in the baseline condition than in the interference condition for both word and picture pairs. Thus, discrimination was greater in the baseline than in the interference condition.

Paired t-tests comparing responses between conditions within stimuli confirmed that for both word pairs and picture pairs remember false alarms increased in the interference condition, whereas remember hit rates remained the same. For word pairs, there was no effect of interference on remember hits [ $t(26) = .892, p = .380$ ], similarly for picture pairs, there was no effect of interference on remember hits [ $t(23) = .736, p = .469$ ]. However, for word pairs, interference increased remember false alarms [ $t(26) = 4.054, p < .001$ ]. Similarly for picture pairs, remember false alarms were increased due to interference [ $t(23) = 6.840, p < .001$ ].

#### *Analyses of IRK old responses*

The mean proportion of know responses, and the proportion of know responses estimated using the independence assumption are also shown in Table 2 A 2 (Stimuli: word vs picture pairs) X 2 (Condition: Baseline vs Interference) X 2 (Probe: Intact vs Rearranged) (ANOVA) was conducted on IRK old responses.

There was no significant main effect for test probe [ $F(1, 49) = 3.053, MSe = .696, p = .087$ ]. Thus, familiarity-based know responses did not show any discrimination between intact and rearranged test pairs. This would be expected if know responses were based on the familiarity on the individual items in each test pair. There was also no significant main effect for stimuli [ $F(1, 49) = .003, MSe = .001, p = .955$ ]. However, there was a significant main effect for condition [ $F(1, 49) = 18.235, MSe = 5.161, p < .001$ ], overall IRK responses were significantly higher in the interference condition than in the baseline condition. Thus, interference significantly increased the proportion of familiarity-based responses.

The interactions between stimuli and probe [ $F(1, 49) = 2.227, MSe = .508, p = .142$ ], condition and stimuli [ $F(1, 49) = .580, MSe = .164, p = .450$ ], between condition and probe [ $F(1,$

49) = 456,  $MSe = 1\,992$ ,  $p = .164$ ], and the interaction between all three factors [ $F(1, 49) = 1\,638$ ,  $MSe = 375$ ,  $p = .207$ ] were not significant

#### *Analysis of Corrected Recognition scores*

To examine discrimination between conditions, corrected recognition scores (hit rate minus false alarm rate) were calculated. These means are also shown in Table 2. A 2 (Stimuli: word pairs vs. picture pairs) X 2 (Condition: Baseline vs. Interference) ANOVA for corrected recognition scores was conducted. There was a main effect for condition [ $F(1, 49) = 54.706$ ,  $MSe = 2.075$ ,  $p < .001$ ] showing that there was a significant difference in discrimination responses between the baseline and interference conditions. That is, discrimination significantly decreased with interference. There was no main effect for stimuli [ $F(1, 49) = 3.216$ ,  $MSe = .265$ ,  $p = .079$ ] showing that there was no difference in overall discrimination between the word and picture pair conditions. The interaction between stimuli and condition was not significant [ $F(1, 49) = .423$ ,  $MSe = .016$ ,  $p = .518$ ].

#### **Discussion**

As expected, there was a picture superiority effect. That is, the hit rate was significantly greater for picture pairs than word pairs in the baseline condition. In addition, this advantage was seen in a non-mirror pattern. The advantage in picture pair recognition was seen only in the hit rate as there was no difference in the false alarm rates between picture and word pairs. These results provide a between-subjects replication of Hockley's (2008) picture superiority effect for associative recognition. Moreover, the finding of picture superiority is novel for this study, because Hockley (2008) used a within-subject design.

Interestingly, although there was a picture superiority effect in overall hit rates, the remember responses and familiarity estimates in the baseline condition for picture pairs were not

significantly different from word pairs. This is in contrast to Rajaram's (1993) finding of a significant increase in remember responses for pictures in item recognition.

Moreover, the findings regarding the effect of interference on recognition hits and false alarms for word and picture pairs were similar to Verde's (2004) findings. It was predicted based on Verde's (2004) findings that interference would reduce the likelihood of recollecting associations but increase item familiarity. For word pairs, Verde (2004) found an increase in hit rates and an increase in false alarm rates with increases in interference. Consistent with this, there was both an increase in recognition hit rates and recognition false alarms for word pairs with interference in the current experiment. Interestingly, for picture pairs there was a slight increase in recognition hit rates but a significant increase in recognition false alarms with interference. Interestingly, picture pairs had slightly higher hit rates than word pairs in the interference condition, because the interference condition only increased the item familiarity strength not the item associations. These findings support Verde's (2004, Exp. 3) finding for word pairs. It should be noted, however, that Verde (2004) did not have a baseline condition, but rather manipulated the amount of interference. It is probable that with interference, item familiarity played a larger role in the retrieval process than recollection.

The question that arises is why did recognition hits not increase significantly with interference for picture pairs as it did for word pairs? The answer is likely that the picture superiority effect was reduced with interference. In the baseline condition, pictures were more distinctive than word pairs and so a picture superiority effect was present. That is, pictures receive more extensive semantic processing than do words (Nelson et al., 1977; Weldon & Rodiger, 1987), therefore, pictures benefit from deeper or more elaborate levels of processing (Craik & Lockhart, 1972) making them more distinctive than words. The increase in item

familiarity with interference likely eliminated the distinctiveness of pictures. That is, the interference manipulation increased the strength of item familiarity and not associations between items. Indeed, item familiarity was instrumental in increasing hit rates for word pairs and not for picture pairs. Moreover, item familiarity increased false alarms for word pairs and picture pairs. Thus, there was a reliance on item familiarity on correct rejection of rearranged pairs in the interference condition, because for both word pairs and picture pairs, interference made the recall-to-reject strategy less useful.

The interpretation that the effects of interference on recognition hit rates and false alarms are due to an increase in item familiarity strength is strongly supported by the remember and independent know responses. For both word pairs and picture pairs, remember hit rate did not change significantly, whereas the IRK hit rate significantly increased in the interference condition. This effect suggests that item familiarity increased with interference and item familiarity played a greater role than recollection in the retrieval process or the decision process in the interference condition for both word pairs and picture pairs. The increase in IRK false alarm rate with interference was also consistent with an increase in item familiarity with interference. The increase in the remember false alarm rate suggests that subjects may have claimed recollection for rearranged pairs due to high similarity of those to memories of studied items. This significant increase in remember false alarm rates with interference in Experiment 1 contrasts with Verde's (2004) finding of a marginal increase in remember false alarms in the interference condition.

When examining the corrected recognition scores for recognition responses, further support was provided for the view that the increase in hit and false alarm rates with interference

occurred due to an increase in item familiarity strength. In fact, there was a decrease in discrimination with interference for both picture pairs and word pairs.

## **Experiment 2**

The goal of Experiment 2 was to investigate if the effect of interference on associative recognition was also determined by the strength of familiarity of the individual items within the pairs. In addition, Experiment 2 was conducted to examine the effects of familiarization on distinctiveness. That is, would an increase in item familiarity due to interference in Experiment 1 explain why the picture superiority effect was eliminated because of interference?

Whereas in Experiment 1 items were repeated across pairs in the interference condition, Experiment 2 was designed to independently manipulate the magnitude of item familiarity on associative recognition in the absence of interference. This was done by presenting half of the items in a familiarization list prior to the study and test list for associative recognition. That is, in the association study list, participants studied pairs that contained items that were presented once (i.e. familiar) in the first study list and studied pairs that contained items that were not presented in the first list. Thus, there were two types of pairs presented at test, familiar and non-familiar. It was expected that for both word and picture pairs, there would be greater hit rates in the familiar than the unfamiliar conditions.

Previous research has shown that increasing pair strength results in an increase in hit rate but no change in false alarm rate for strong and weak intact and rearranged word pairs (Cleary, Curran & Green, 2001, Kelley & Wixted, 2001, Verde & Rotello, 2004). It was assumed that the false alarm rate did not change because the increase in item familiarity for the rearranged pairs was offset by an increase in the probability of recall-to-reject for the stronger pairs.

A notable difference in the current experiment was that item familiarity was increased independently of associative information. Therefore, it was expected that increased item familiarity would increase both the hit and false alarm rates. The hit rates would increase because item familiarity would augment the retrieval of associative information. The false alarm rate would increase because there is no increase in recall-to-reject to offset the increase in item familiarity.

In Experiments 2 and 3, response time was also analyzed as a dependent variable as it is commonly assumed that responses based on familiarity are fast decisions whereas responses based on recollection are slower in comparison. Therefore, response time provides another means of distinguishing between familiarity and recollection. As a consequence, the yes-no procedure was used rather than the remember-know procedure.

## **Method**

*Participants* Eighty-nine undergraduate university students were tested. After removal of seven data files due to chance discrimination in the control condition, 41 participants took part in the word pair condition and 41 participants took part in the picture pair condition.

*Apparatus and Materials* The apparatus and stimulus materials were the same as in Experiment 1.

*Procedure* The procedure was similar to Experiment 1 except for two modifications. The first study list contained a list of 64 items. These items were shown one at a time. The second study list contained 64 study pairs. Half of the pairs consisted of two items that were shown in the first study list (i.e., familiar items), and half of the pairs consisted of items that had not been shown previously (i.e., unfamiliar items). The test list consisted of 64 intact pairs (i.e., half familiar pairs and unfamiliar pairs) and 64 rearranged pairs (i.e., half familiar pairs and half

unfamiliar pairs) The familiar pairs had appeared as single items in the first study list and as pairs in the second study list The unfamiliar pairs only appeared in the second study list There was another study phase included and remember and know responses were not recorded Before the presentation of pairs to study there was another study phase in which a total of 64 individual items were shown Then pairs of items in the second study phase were presented Half of the pairs consisted of two items that were shown in the first study list (i.e., familiar items), and half of the pairs contained items that had not been shown previously (i.e., non-familiar items) Each pair appeared in the center of the screen for 4,000 msec Following completion of the second study phase, participants were given instructions by the Experimenter regarding old and new judgments During the test phase, each trial began with a fixation line of “+” symbols displayed in the center of the screen for 1,000 msec A test word pair or picture pair replaced the fixation line and remained until the participant responded The “z” and “/” keys were used to report new and old judgments respectively

*Design* The Experiment was a 2 (stimuli words vs pictures) X 2 (items familiar vs unfamiliar) analysis of variance (ANOVA) design Stimuli was the only between-participants variable The dependent variables were recognition accuracy and response latency

## **Results**

The proportion of hits (correct old responses to intact pairs) and false alarms (incorrect old responses to rearranged test pairs) for the word and picture pairs in both the familiar and unfamiliar conditions are shown in Table 3

### *Analyses of Recognition Responses*

A 2 (Stimuli word vs picture pairs) X 2 (Condition Familiar vs Non-familiar) X 2 (Probe Intact vs Rearranged) mixed factor ANOVA was conducted on the proportions of old



recognition responses. This analysis revealed a main effect of test probe [ $F(1, 80) = 629.656$ ,  $MSe = 29.330$ ,  $p < .001$ ]. That is, the hit rate was significantly higher than the false alarm rate showing that overall discrimination performance was above chance. There was also a main effect of type of stimuli [ $F(1, 80) = 7.375$ ,  $MSe = 146$ ,  $p = .008$ ], overall old responses were higher for picture pairs than word pairs. However, the main effect of condition was not significant [ $F(1, 80) = 1.871$ ,  $MSe = .019$ ,  $p = .175$ ] indicating that overall hit rates and false alarms did not differ by the level of familiarity.

The interactions between condition and stimuli, [ $F(1, 80) = 1.551$ ,  $MSe = .016$ ,  $p = .217$ ], and between probe and stimuli were not significant [ $F(1, 80) = 1.731$ ,  $MSe = .081$ ,  $p = .192$ ]. The main effect of probe was qualified by a significant interaction between condition and test probe [ $F(1, 80) = 13.082$ ,  $MSe = 141$ ,  $p = .001$ ]. That is, there was a significantly greater difference between hit rates and false alarm rates in the familiar condition than in the non-familiar condition. The interaction between stimuli, condition and probe was also significant [ $F(1, 80) = 7.042$ ,  $MSe = .076$ ,  $p < .05$ ]. Independent sample two-tailed t-tests confirmed that hit rate was greater for picture pairs than for word pairs only in the familiar condition [ $t(80) = -2.857$ ,  $p < .05$ ], but not in the unfamiliar condition [ $t(80) = -1.578$ ,  $p = .119$ ]. Paired t-tests confirmed for picture pairs that hit rates were not higher in the familiar condition [ $t(41) = 1.817$ ,  $p = .077$ ] and false alarm rates were not significantly different between familiar and unfamiliar conditions [ $t(41) = .018$ ,  $p = .442$ ]. In contrast, for the word pair condition, hit rates were not significantly different in the familiar condition [ $t(40) = 1.817$ ,  $p = .077$ ] and false alarm rates were also not significantly different in the familiar condition [ $t(40) = .777$ ,  $p = .442$ ].

### *Analysis of Corrected Recognition Scores*

The mean corrected recognition scores are also presented in Table 3. A 2 (Stimuli: word pairs vs. picture pairs) X 2 (Condition: Familiar vs. non-Familiar) ANOVA for corrected recognition scores was conducted. There was a main effect for condition [ $F(1, 80) = 13.082, MSe = 281, p = .001$ ]. This effect indicates that discrimination was greater in the familiar condition than in the non-familiar condition. There was no main effect for stimuli [ $F(1, 80) = 1.731, MSe = 161, p = .192$ ]. The interaction between stimuli and condition [ $F(1, 80) = 7.042, MSe = 151, p < .05$ ] was also significant. There was a greater difference in discrimination between the familiar condition and non-familiar condition for picture pairs than word pairs. That is, for picture pairs, discrimination in the familiar condition was significantly higher than in the unfamiliar condition. In contrast, discrimination was the same in familiar and unfamiliar conditions for word pairs.

### *Analysis of Recognition Response Times*

A yes-no response procedure was used in Experiment 2. This response procedure is simpler than remember-know response procedure, and allows for an analysis of the mean response times of the correct old and new responses. The mean response times for each condition are shown in Table 4. These results were analyzed to determine if familiarity increased mean response times for hits and correct rejections.

A 2 (Stimuli: word pairs vs. picture pairs) X 2 (Condition: Familiar vs. non-Familiar) X 2 (Probe: intact vs. rearranged) was conducted on mean correct response times. There were no significant main effects for condition. The only significant main effect was for stimuli [ $F(1, 80) = 7.887, MSe = 3041.45, p < .05$ ]. The main effect of stimuli was qualified by a significant interaction between stimuli and probe [ $F(1, 80) = 4.796, MSe = 2538294.033,$

$p < .05$ ] That is, response time for correct responses (i.e., hits and correct rejections) for picture pairs was significantly faster in the familiar condition, than in the unfamiliar condition. However, recognition response times (i.e., hits and correct rejections) for word pairs was similar in the familiar and unfamiliar conditions. Independent t-tests confirmed that response time for correct rejections was significantly faster for picture pairs than word pairs in the familiar condition [ $t(80) = 3.249, p = .002$ ] and response time for hits was significantly faster for picture pairs than word pairs in the familiar condition [ $t(80) = 2.032, p = .045$ ]. Moreover, there was a trend for response time for hits to be significantly faster for picture pairs than word pairs in the non-familiar condition [ $t(80) = 1.968, p = .053$ ].

## **Discussion**

The picture superiority effect was only seen in the familiar condition. An increase in hit rate due to item familiarity was only found in the picture pair condition, and not in the word pair condition. Repeating pictures only once was enough to increase recognition hit rates in the familiar condition, whereas for words there was no significant effect of familiarity.

The findings of Experiment 2 raise two issues. Firstly, it is unclear why the picture superiority effect was not present in the unfamiliar (or control) condition. It would be expected, since the unfamiliar condition was similar to the baseline condition in Experiment 1. Secondly, it is unclear from the results why hit rates in the familiar condition for the word pair condition were similar to that of the unfamiliar condition. Since words in the familiar condition were repeated, this finding was unexpected. Perhaps because words are less distinctive and processed less deeply than pictures, repeating words once did not increase hit rates in the familiar condition.

The results of Experiment 2 may have differed from predictions because the manipulation of familiarity was not great enough. In their comparison of strong versus weak

pairs, Kelley and Wixted (2001) presented the strong pairs four times. Therefore, in Experiment 3 the familiarized items were presented four times in the first study list and the major prediction was that familiarization would make pictures less distinctive. The predictions were the same as for Experiment 2.

### **Experiment 3**

#### **Method**

*Participants* There were 98 participants consisting of undergraduate university students. After removal of eight data files due to chance discrimination in the control condition, 46 participants took part in the word pair condition and 44 participants took part in the picture pair condition.

*Apparatus and Materials* The apparatus and stimuli were the same as in Experiment 2.

*Procedure* The procedure was similar to that of Experiment 2 except for one change. The familiarized items presented in the first study list were shown four times rather than once. Thus, the new list length for the first list was 256 items. The order of repeated presentations in the first list was random.

#### **Results**

##### *Analyses of Recognition Responses*

The proportion of hits and false alarms for the word and picture pairs in both the familiar and unfamiliar conditions are given in Table 4. A 2 (Stimuli: word vs. picture pairs) X 2 (Condition: Familiar vs. Non-familiar) X 2 (Probe: Intact vs. Rearranged) mixed factor ANOVA was conducted on the proportions of old recognition responses. This analysis revealed a main effect of test probe [ $F(1, 88) = 583.746, MSe = 28.416, p < .001$ ]. That is, the hit rate was

significantly higher than the false alarm rate showing that overall discrimination performance was above chance. There was no main effect of type of stimuli [ $F(1, 88) = 1.360, MSe = 0.039, p = 0.247$ ]. That is, overall old responses were similar for picture pairs than word pairs. The main effect of condition was significant [ $F(1, 88) = 10.227, MSe = 0.137, p = 0.002$ ] indicating that overall hit and false alarms were significantly higher in the familiar than in the non-familiar conditions.

The interactions between condition and stimuli, [ $F(1, 88) = 2.76, MSe = 0.004, p = 0.601$ ], probe and stimuli, [ $F(1, 88) = 1.252, MSe = 0.061, p = 0.266$ ], and between familiarity, test probe and stimuli [ $F(1, 88) = 0.402, MSe = 0.005, p = 0.528$ ] did not approach significance.

#### *Analysis of Corrected Recognition Scores*

A 2 (Stimuli: word pairs vs. picture pairs) X 2 (Condition: Familiar vs. non-Familiar) ANOVA for corrected recognition scores was conducted. There was no main effect for condition [ $F(1, 88) = 0.750, MSe = 0.020, p = 0.389$ ] showing that there was no difference in discrimination between the familiar and non-familiar conditions. There was no main effect for stimuli [ $F(1, 88) = 1.252, MSe = 0.122, p = 0.266$ ] showing that there was no difference in discrimination between the picture and word pairs. The interaction between stimuli and condition [ $F(1, 88) = 0.402, MSe = 0.011, p = 0.528$ ] was also not significant.

#### *Analysis of Recognition Response Times*

Mean response times for each condition are shown in Table 6. A 2 (Stimuli: word pairs vs. picture pairs) X 2 (Condition: Familiar vs. non-Familiar) X 2 (Probe: intact vs. rearranged) was conducted on mean correct response times. There was no significant main effect for condition [ $F(1, 88) = 0.035, MSe = 18837.211, p = 0.852$ ]. There was a significant main effect for test probe [ $F(1, 88) = 38.097, MSe = 2284692.71, p < 0.001$ ]. That is, reaction time for hits was

significantly lower than correct rejections. There was no significant main effect for stimuli [ $F(1, 88) = 1.517, MSe = 1964154.817, p = .221$ ]. The main effect of test probe was qualified by a significant interaction between condition and probe [ $F(1, 88) = 12.003, MSe = 5393432.332, p = .001$ ]. That is, the response time for correct responses (i.e., hits) for picture pairs was significantly faster than that of word pairs. Independent t-tests confirmed that response time for hits was faster for picture pairs in the non-familiar condition [ $t(88) = 2.774, p < .05, p = .007$ ], however response times for correct rejections were similar in the familiar condition [ $t(88) = 2.07, p = .231$ ]. In contrast to Experiment 2, response time for correct rejections was similar for picture pairs and word pairs in the familiar condition [ $t(88) = -.327, p = .744$ ] and response time for hits was similar for picture pairs than word pairs in the familiar condition [ $t(80) = 2.032, p = .045$ ].

## Discussion

As can be seen from the results of Experiment 3, increasing the familiarization to three repetitions for items had different effects than repeating items once as in the case of Experiment 2. In Experiment 2, it was found that hit rates were higher in the familiar condition only for picture pairs. Moreover, false alarm rates for picture pairs were significantly lower in the familiar condition. In contrast, the results of Experiment 3 showed a different pattern of results.

Firstly, there was no picture superiority effect present in either the non-familiar or familiar conditions in Experiment 3. Secondly, for word and picture pairs, both hit and false alarm rates were significantly higher in the familiar condition. This finding supports what Kelly and Wixted (2001) would predict based on their "some or none model". In the case of the present experiment, only item familiarity was increased. The false alarm rate increased because there was no corresponding increase in associative information that would support recall-to-

reject and thus counter the increase in familiarity Verde and Rotello (2004) found the same pattern of results in their manipulation of associative interference The results of Experiment 3 indicate that the effects of interference on associative recognition of picture pairs and word pairs are due to item familiarity

The picture superiority effect was not present in terms of accuracy in the non-familiar conditions for both Experiment 2 and Experiment 3 It is possible that this may be due to the test list containing pairs from both the familiar and non-familiar conditions This is in contrast to the test lists in Experiment 1 (and Experiment 4), where the test lists did not contain familiar and non-familiar pairs Interestingly, when examining response times, for Experiment 2, there was a trend for faster old (i.e. hits) response times for picture pairs in the non-familiar condition, whereas in Experiment 3 there were significantly faster hit response times picture pairs in the non-familiar condition This suggests that the picture superiority was present in the form of faster hit rate response times rather than higher hits in Experiment 3 A tentative explanation would be that pictures may be distinctive as a group of stimuli, rather than individually, and familiarizing half of the pictures decreases the distinctiveness of all of the similar pictures in a group Perhaps, due to similar perceptual relationship of pictures to each other, familiarizing half the items would enable unfamiliarized pictures that share a similar relationship to be familiarized as well

#### **Experiment 4**

The goal of Experiment 4 was to replicate Verde's interference effect for word pairs studied in sentences There were two conditions general noun and specific location or specific noun and specific location An example of a sentence in the general condition would be "The Academic is in the Gymnasium" An example of a sentence in the specific condition would be "The Chemist is in the Gymnasium" It was expected that the specific noun and specific location

would share a similar deep encoding as picture pairs. One could argue that the pictures/line drawings are not encoded more deeply than words in the previous experiments, but that the encoding of the pictures was more specific whereas the instantiation of the words was more general. It is easier to remember something that is more specific or unique than something that is more general because it is less similar to anything else and thus suffers from less interference.) Thus, recognition hit rates would be higher for specific nouns in the baseline and interference conditions. Moreover, in the baseline condition, recognition hit rates would be higher for specific nouns than general nouns, because general nouns are encoded as specific instantiations (Anderson et al., 1976). In addition, false alarm rates would be similar in both conditions. In the interference condition similar to Experiment 1, for the specific condition, there would be higher recognition hit rates for specific nouns, whereas the recognition false alarm rate would increase in the interference condition. Similarly in the interference condition, there would be lower recognition hit rates for general nouns, whereas the recognition false alarm rate would increase in the interference condition. For meaningful stimuli such as words encoded in sentences, as Verde (2004) suggested from his first Experiment, recollection plays a greater role in recognition, therefore with interference, recognition hit rates would decrease with interference for both general and specific nouns. The remember-know procedure was also used in Experiment 4 in order for a valid comparison to the results of Experiment 1. Moreover, remember-know procedure was used to determine if recollection was reduced and item familiarity was increased with interference. It was predicted since recollection was reduced with interference, remember hits would decrease and remember false alarms would increase. Moreover, since item familiarity was increased due to interference, IRK hits and IRK false alarms would increase with interference.



## Method

*Participants* Fifty-one undergraduate university students participated for course credit. Nine participant data files were not included in the analyses because of chance performance in the baseline conditions. Thus, a total of 49 participants took part in the study with 25 participants in the general sentence condition and 24 participants in the specific sentence condition.

*Apparatus* The apparatus was the same as in Experiment 1.

*Materials* “The Academic is in the Gymnasium” And an example of a sentence in the specific condition would be “The Chemist is in the Gymnasium” The stimuli came from an expanded version of Battig and Montague (1969) norms (Overschelde, Rawson & Dunlosky, 2004). The words were selected based on the fourth least frequent. The number of sentences used was for the study phase, 16 sentences in baseline and 16 sentences in interference. The test phase contained 64 sentences. Moreover, the two conditions were general and specific. Refer to Appendix 7 for details on sentences used.

*Procedure* Prior to the start of the Experiment, participants were randomly assigned to either general noun or specific noun condition. The 35-min session consisted of a study phase, and a test phase. During the study phase, each word pair (i.e., general subject noun and location or specific subject noun and location) appeared in a sentence (ex “The Criminal is in the Laundry”, ex “The Robber is in the Laundry”) on the center of the screen for 4,000 msec, followed by a 1,000 msec blank interval. The participants were instructed to learn the words in the sentence for a memory test to follow. The participants were given the following instructions “Try to associate each pair of nouns in the sentences so that you will remember which nouns were shown together” To summarize, the participants were told that remembering is the ability

to consciously bring back details of the study episode, such as where in the study list an item had appeared or what images or associations it had invoked at the time, and that knowing is a sense of familiarity in the absence of such detail. During the test phase, each trial began with a fixation line of “+” symbols displayed in the center of the screen for 1,000 msec. A test sentence replaced the fixation line and remained until the participant responded. For each sentence presented at test, the participant had four choices for key presses. The “z” key was pressed for new, familiar judgments. The “c” key was pressed for new, remember judgments. The “,” key was pressed for old, familiar judgments. And the “/” key was pressed for old, remember judgments.

## **Results**

### *Analyses for Recognition responses*

The proportions of overall old, remember, and know responses for each probe, sentence and interference condition are presented in Table 7. A 2 (Stimuli: General vs. Specific) X 2 (Condition: Baseline vs. Interference) X 2 (Probe: Intact vs. Rearranged) (ANOVA) was conducted on the proportions of old recognition responses. There was a significant main effect for condition [ $F(1, 47) = 90.275, MSe = 2.117, p < .001$ ], indicating overall old responses were reliably higher in the interference condition than in the baseline condition. There was also a main effect for test probe [ $F(1, 47) = 254.795, p < .001$ ]. The hit rate was significantly higher than the false alarm rate, showing that overall discrimination performance was above chance. The main effect for type of stimuli approached significance [ $F(1, 47) = 3.967, p = .052$ ]. The trend was for overall old responses to be greater in the specific condition than in the general condition. The interactions between condition and stimuli [ $F(1, 47) = .151, MSe = .004, p = .699$ ], stimuli and test probe [ $F(1, 47) = .012, MSe = .000, p = .913$ ] were not significant. The main effects of condition and probe were qualified by a significant interaction between the condition and test

probe [ $F(1, 47) = 90.806, MSe = 1.133, p < .001$ ] That is, there was a significantly greater difference between hit rates and false alarm rates in the base line condition than in the interference condition for both general and specific sentences. Finally, there was a significant interaction between type of stimuli, condition and probe [ $F(1, 47) = 5.112, MSe = .064, p = .028, p < .05$ ]

Post-hoc tests were conducted to explain the findings. Paired sample t-tests confirmed only overall false alarm rates increased with interference. There was no effect of the interference condition on recognition hits for general sentences [ $t(24) = 1.964, p = .061$ ] and specific sentences [ $t(23) = -.947, p = .354$ ]. In contrast, in terms of false alarms, the interference condition produced a significant increase in false alarms for general sentences [ $t(24) = -8.136, p < .001$ ] and specific sentences [ $t(23) = -10.949, p < .001$ ].

An independent sample two-tailed t-test [(Baseline Specific Intact vs General Intact)] confirmed that hit rate was greater for Specific sentences than for General sentences only in the baseline condition [ $t(47) = -2.275, p < .05$ ], whereas there was no difference in false alarm rates in the baseline condition between specific sentences and general sentences [ $t(47) = -.539, p = .592$ ]. Furthermore, independent sample two-tailed t-tests confirmed there was no difference in hit rates in the interference condition between general and specific sentences [ $t(47) = .707, p = .483$ ] and no difference in false alarm rates in the interference condition between general and specific sentences [ $t(47) = -1.872, p = .067$ ].

#### *Analyses for Remember responses*

A 2 (Stimuli: general vs specific) X 2 (Condition: Baseline vs Interference) X 2 (Probe: Intact vs Rearranged) ANOVA was conducted on overall old remember responses. There was a significant main effect for test probe [ $F(1, 47) = 141.375, MSe = 5.308, p < .001$ ]. The

remember hit rate was significantly higher than the remember false alarm rate showing that discrimination of remember responses was above chance. There was no significant main effect for stimuli [ $F(1, 47) = 3.17, MSe = 0.84, p = .317$ ]. However, there was a significant main effect for condition [ $F(1, 47) = 12.639, MSe = 356, p = .001$ ], indicating overall old responses were reliably higher in the interference condition than in the baseline condition. The interaction between stimuli and test probe [ $F(1, 47) = 3.15, MSe = 0.12, p = .577$ ] and between all three factors [ $F(1, 47) = 0.27, MSe = 0.64, p = .871$ ], were not significant. The main effects of condition and probe were qualified by a significant interaction between the condition and test probe [ $F(1, 47) = 34.928, MSe = 648, p < .001$ ]. That is, there was a significantly greater difference between mean remember hit rates and mean remember false alarm rates in baseline condition than in the interference condition for both general and specific sentence conditions.

Paired sample t-tests confirmed only overall remember false alarm rates increased with interference. The interference condition did not produce an effect on remember hits for general sentences [ $t(24) = 0.934, p = .359$ ] and specific sentences [ $t(23) = -0.947, p = .354$ ]. In contrast, in terms of remember false alarms, the interference condition produced an increase in remember false alarms for general sentences [ $t(24) = -5.950, p < .001$ ] and specific sentences [ $t(23) = -5.588, p < .001$ ].

#### *Analyses for IRK responses*

The same ANOVA was carried out for the IRK estimates. There were no significant main effect for stimuli [ $F(1, 47) = 1.465, MSe = 203, p = .232$ ]. However, there was a significant main effect for condition [ $F(1, 47) = 48.449, MSe = 2.449, p < .001$ ]. That is, there were significantly higher old IRK responses in the interference condition. Moreover, there was a

significant main effect for test probe [ $F(1, 49) = 36.901, MSe = 1.444, p < .001$ ] That is, there were significantly higher overall mean IRK hit rates than mean IRK false alarm rates

There was no significant interaction between stimuli and test probe [ $F(1, 47) = .038, MSe = .001, p = .846$ ] Furthermore, there was no significant interaction between condition and stimuli [ $F(1, 47) = .591, MSe = .015, p = .591$ ] However, there was no significant interaction between the condition and test probe [ $F(1, 49) = 3.306, MSe = .078, p = .075$ ] That is, there was no significantly greater difference between IRK hit rates and IRK false alarm rates in base line condition than in the interference condition for both word and picture pairs

Interestingly, there was a significant interaction between all three factors [ $F(1, 47) = 8.763, MSe = .207, p = .005$ ] Paired sample t-tests confirmed only IRK hit rates for specific sentences did not increase with interference. The interference condition produced a significant effect on IRK hits for general sentences [ $t(24) = 3.993, p = .001$ ], but not for specific sentences [ $t(23) = -1.587, p = .126$ ]. For IRK false alarms, the interference condition produced an increase in IRK false alarms for general sentences [ $t(24) = -5.128, p = .001$ ] and specific sentences [ $t(23) = -7.645, p < .001$ ]

#### *Analysis of Corrected Recognition scores for Recognition*

A 2 (Stimuli: general vs. specific) X 2 (Condition: Baseline vs. Interference) ANOVA for corrected recognition scores was conducted. There was a main effect for condition [ $F(1, 47) = 90.806, MSe = 2.267, p < .001$ ] showing that there was a significant difference in overall discrimination between the baseline and interference conditions. That is, overall discrimination decreased in the interference condition. There was no main effect for stimuli [ $F(1, 47) = .012, MSe = .001, p = .913$ ] showing that there was no difference in discrimination between the general

and specific conditions. The main effect for condition was qualified by a significant interaction between stimuli and condition [ $F(1, 47) = 5.112, MSe = .128, p = .028$ ].

## Discussion

The overall patterns of old responses and of remember and IRK estimates in Experiment 4 were virtually identical to the results of Experiment 1, suggesting the encoding of specific nouns is similar to picture pairs. Thus, the specific-noun condition in Experiment 4 can be considered as similar to picture pairs, since picture pairs also share similar deep semantic encoding or specific/unique encodings. It is this specific/unique encoding that makes both picture pairs and specific nouns more distinctive than word and general nouns. Moreover, general nouns in sentences can be considered as similar to word pairs, since word pairs share similar shallow encoding or general instantiations. As expected from the instantiation principle, in the baseline condition there were significantly greater recognition hits in the specific sentence condition than in the general sentence condition. Furthermore, the false alarms were not significantly different between both sentence conditions in the baseline condition. Thus, there was a non-mirror pattern similar to what was present in the picture superiority effect.

Similar to the first experiment, the non-mirror pattern was eliminated in the interference condition. As in Experiment 1, it was found in Experiment 4, there was a significant increase in recognition false alarms with interference in both general and specific conditions. Moreover, recognition hits did not increase with interference in specific condition similar to picture pair condition in Experiment 1. Furthermore, similar to Experiment 1 there was an increase in remember false alarms and no effect on remember hits with interference. The increase in false alarms in the current experiment supports the theory that item familiarity contributes more to recognition than recollection when interference is present.

In addition, in the current experiment, recognition hit rates did not change due to interference in the specific sentence condition. However, the recognition hit rate increased significantly with interference in the general sentence condition, because familiarity contributed significantly to retrieval for the general noun and location pairs. In contrast, Verde (2004) found a significant decrease in recognition hit rates with interference when professions and locations were encoded in sentences. The question arises, why did Verde (2004) find different results with sentences in terms of the effects of interference? The likely reason is that Verde (2004) in his first experiment used only specific professions such as doctor, academic, engineer and did not include objects and animals. Perhaps, restricting stimuli to a specific category which share some attributes would increase or magnify the effects of interference, thus decreasing hit rates and increasing false alarm rates.

There was an increase in IRK false alarms due to interference for both general and specific sentence conditions. This supports the theory that familiarity strength or item familiarity plays a more dominant role than recollection in associative recognition when interference is present. However, IRK hit rates only increased due to interference for the general sentence condition. This contrasting finding for the specific sentence condition differs from Verde's (2004) Experiment 1 finding. It is probable the difference is due to type of nouns embedded in the sentences. Whereas Verde (2004) presented professions and locations in sentences, in the current study, random nouns representing objects were presented. It is likely the level of interference created by presenting professions is higher, since professions share some similarities with each other. This would explain why IRK hit rates increased due to interference in Verde's (2004) study, but not with specific nouns in sentences for the current study.

Similar to Experiment 1, when examining the corrected recognition responses for recognition, further support was provided for the theory that increases in hit and false alarm rates with interference were due to an increase in item familiarity strength. Similar to Experiment 1, there was a decrease in discrimination with interference for both general noun and specific nouns.

### **General Discussion**

The primary goal of this study was to determine if associative recognition memory is supported by two retrieval processes as posited by the dual process theory or one retrieval process as posited by the single process theory. This goal was achieved through three manipulations in four experiments. The three manipulations were interference, stimulus type, and the level of item familiarity. The analysis of overall recognition accuracy was supplemented with Tulving's (1985) remember/know response procedure and the analysis of yes/no recognition decision response times in different experiments to provide further tests of dual and single process theories.

#### *Interference effects on recognition of picture pairs and word pairs*

The first experiment in the current study examined the effect of interference on associative recognition of picture pairs and word pairs. According to both dual and single process theories, interference increases recognition hits and false alarms for word pairs (Verde, 2004, Dyne et al., 1990). According to Verde (2004), familiarity strength necessary for recognition hits had increased due to interference, whereas recollection necessary for correct recognition had decreased due to interference. In support Verde (2004) found false alarm rates and independent know hit rates to increase significantly with the degree of interference.



Furthermore, Verde (2004) found that remember hit rates decreased and remember false alarms increased with the degree of interference

Single process theory would explain the effects of interference on associative recognition as increasing item familiarity strength resulting in increasing hit rates but reducing associative familiarity strength resulting in increased false alarm rates. When the effects of interference on recognition of picture pairs and word pairs were compared in Experiment 1, strong support was provided for Verde (2004) findings and the dual process theory. Firstly, support for the dual process theory came from a replication of Hockley's (2008) non-mirror effect in the baseline condition. There were significantly higher recognition hit rates for picture pairs than word pairs. Moreover, the recognition false alarm rates for picture pairs and word pairs were not significantly different in the baseline condition. Hockley (2008) suggested that picture pair presentations can be considered as another way of strengthening the encoding of both item and associative information, as it produces the same non-mirror pattern as Kelley and Wixted (2001) found for repeating word pairs. Even though the present study used a between-subject design, a non-mirror pattern was still found. Picture pairs are better encoded than word pairs, but the effectiveness of the recall-to-reject is similar for both types of pairs. Thus, the findings for associative recognition of word pairs and picture pairs in the baseline condition are consistent with the dual process account. In contrast, a single process account would suggest the type of stimuli encoded has no effect on recognition hit rates. That is, hit rates only depend on item familiarity and not item type.

Further support is provided for the dual process theory from remember and know responses. If the picture superiority effect is due to greater use of recollection, then significantly higher remember responses must be present in the baseline condition. This was not found in

Experiment 1 suggesting the picture superiority effect present for pairs not items is due to item distinctiveness. In fact, Rajaram (1993) found a picture superiority effect in item recognition, but also found significantly higher remember responses for correct recognition of pictures.

Secondly, when examining the effects of interference on word pairs and picture pairs, the results strongly supported Verde's (2004) study. In fact, due to interference, the role of recollection was reduced, but item familiarity was relied upon for retrieval for both intact and rearranged pairs. For word pairs, recognition hit rates increased significantly with interference, whereas for picture pairs, there was a slight increase in hit rates with interference. The effects of reduction of recollection with interference on recognition, was clearly seen for false alarm rates. For both word pairs and picture pairs, there was a significant increase in false alarm rates with interference. In fact, the picture superiority effect was reduced in the interference condition.

Importantly, remember and IK responses were clearly affected by interference for both word pairs and picture pairs. For both word pairs and picture pairs, IK hit rate significantly increased with interference. Moreover, IK and Remember false alarm rates increased with interference for both word pairs and picture pairs. This important finding supports the claim of the Dual process theory, that remembering which is associated with recollection is reduced with interference and knowing which is associated with familiarity is increased with interference. The net effect of these differential changes in remembering and knowing with interference, is an increase in IK hit rates with interference.

The fact that remember hit and false alarm rates did not decrease significantly with interference for picture pairs and word pairs, contrasts with Verde (2004) finding of a significant decrease in remember hit and false alarm rate with interference. It is likely that the remember/know responses are not a precise method for discriminating between recollection and

familiarity-based decisions as Wixted & Mickes (2010) suggest. However, discrimination decreased significantly with interference. Thus, the findings of Experiment 1 of the current study provided support for the dual process account, even though the results suggested that the remember/know procedure was not a precise method for discriminating recollection and familiarity-based decisions.

*The effects of item familiarity on recognition of word pairs and picture pairs*

Experiment 2 and Experiment 3 were conducted to investigate if the effect of interference on associative recognition was also determined by the strength of familiarity of the individual items within the pairs. Importantly, these two experiments were conducted to determine if the distinctiveness of stimulus pairs was eliminated with interference due to item familiarity. Whereas in Experiment 1, items were repeated across pairs in the interference condition, Experiments 2 and 3 were designed to look at the effects of differentially manipulating the magnitude of item familiarity on associative recognition in the absence of interference. In Experiment 2, items were repeated once in the familiar condition. In Experiment 3, items were repeated three times in the familiar condition. The results for Experiment 2 and Experiment 3 differed in terms of reports of hit rates and false alarm rates. In Experiment 2 there was significant increase in hit rates and a significant decrease in false alarm rates with item familiarity only for picture pairs. However, in Experiment 3, for both picture pairs and word pairs, in the familiarity condition, there was a significant increase in recognition hit rates and false alarm rates. It was argued that the manipulation of familiarity in Experiment 2 was insufficient since the results from Experiment 3 indicated that increasing the magnitude of item familiarity to three was a better indicator of the effects of item familiarity on recognition of word pairs and picture pairs. Indeed, recent studies (Wixted & Kelley, 2001, Verde & Rotello, 2004)

have repeated pairs four or more times and were able to successfully examine the effects of item familiarity and associative information on associative recognition. Moreover, Green (1999) found in an item recognition study that for words, a familiarization frequency of one increased hits by .07 whereas a familiarization frequency of four increased hits by .15.

Since both hit rates and false alarm rates increased for both word pairs and picture pairs in Experiment 3 with an increase in item familiarity, this supported the theory that the increase in hit rates and false alarm rates due to interference in Experiment 1 was due to item familiarity. Moreover, when examining the results of Experiment 3, it was found the results were comparable to Kelly and Wixted's (2001) 'some or none' model. In fact, in Experiment 3 the magnitude of item familiarity was significantly increased compared to associative information, unlike Kelley and Wixted's (2001) study where item and associative information were increased with exactly the same magnitude of four times or more. Thus the results of Experiment 3 support the Kelley and Wixted (2001) "some-or-none" model, because item familiarity was manipulated but not associative information.

Finally, even though a significant picture superiority effect was not found in Experiments 2 and 3, there was a consistent finding for a significantly faster response time for correct recognition of picture pairs than word pairs in non-familiar conditions. Although in Experiment 2, there was a trend for faster response time for recognition of picture pairs in the non-familiar condition.

#### *The effects of interference on specific word pairs and general word pairs encoded in sentences*

Experiment 4 was conducted to examine the effects of interference on specific and general word pairs encoded in sentences. The specific nouns were instantiation of their counterparts, the general nouns. The overall pattern of old responses, and pattern of remember

and IRK estimates in Experiment 4 were exactly identical to the results of Experiment 1 suggesting specific nouns are similar to picture pairs

Therefore, it can be concluded from the findings of Experiments 1 and 4 that picture pairs and specific nouns share similar specific encoding which makes them distinctive from words and general nouns. Thus, picture pairs and specific subject nouns in the sentence condition showed higher hit rates in the baseline condition. This result may be due to pictures and specific nouns being encoded uniquely in memory since they have more distinctive perceptual or semantic features (Nelson et al., 1976), or due to deeper or more extensive semantic processing based on their distinctive features (Nelson et al., 1977, Weldon, Roediger, 1987, Craik & Lockhart, 1972)

The fact that interference eliminated the picture superiority effect and hit rate advantage for specific nouns indicates that familiarization by the process of repeating items within pairs eliminates the distinctiveness of pictures and specific nouns. In effect, pictures and specific nouns become less specific and more familiar in memory due to an increase in item familiarity.

Interestingly, the results of the baseline condition followed that of Anderson et al.'s (1976) study on the effectiveness of type of retrieval cue in recall of original encoded sentence. Anderson and colleagues (1976) found significantly higher proportion of last words of sentences were recalled when the retrieval cue was a specific instantiation, than when the retrieval cue was the general noun that was in the sentence. Unlike, Anderson and colleagues' (1976) study, the current study used a recognition paradigm, but also found that there was a retrieval advantage for specific instantiations, in terms of significantly higher recognition hit rates for specific sentences than general sentences. Unlike Verde's (2004) study, it was found that recognition hit rates did not decrease with interference when word pairs were encoded in sentences. In fact, the type of noun (i.e. specific or general) encoded in the sentence determined recognition hit rates and false

alarm rates in the baseline and interference condition. In contrast to Verde's (2004) study, professions were not the only category of specific words used in the specific condition. Categories included objects, non-professions and animals. Moreover, the specific words were instantiations of the general words encoded in sentences. Interestingly, the results were comparable to that of Experiment 1.

Finally, Experiment 4 is the first experiment of its kind to examine memory for specific instantiations compared to their general noun counterparts in an associative recognition paradigm. It also provides support for the suggestion that pictures may act as specific instantiations of words. This finding is also consistent with the view that the distinctiveness of memories in general benefits recollection as opposed to a general feeling of familiarity.

*Support for the Dual process model or the Single process model?*

Thus, the important question arises as to which model of recognition memory the findings from the current study support. Do the findings from all the experiments support the dual process model or a single process model? The findings from all four experiments support the dual process model. An explanation of why this is so, is necessary.

Firstly, certainly the results from Experiment 1 and 4 support strongly the findings of Verde's (2004) study and are contrary to the predictions of certain Single process theories (i.e. SAM, Minerva II, Matrix and TODAM models) mentioned before supported by Dyne et al.'s (1990) study. However, contrary to Dyne et al. (1990) for both Experiments 1 and 4, interference resulted in a significant increase in hit rates and false alarm rates for all item types (i.e. word pairs, picture pairs and word pairs in sentences). Importantly, in contrast to Dyne et al. (1990) discrimination (i.e., HR-FAR) for recognition responses significantly decreased with interference. Similarly, Verde (2004) found discrimination to be significantly decreased with

interference which supported the predictions of the dual process model. Certainly, Kelley & Waxstedt's (2001) "Some or none" model can account for the findings of Experiment 1 and 4.

Secondly, for both Experiment 1 and Experiment 4, a non-mirror pattern was found for where there were significantly higher hit rates for more distinctive stimuli (i.e., pictures and specific instantiations). Familiarity single based theories cannot explain this finding because picture pairs and specific nouns in sentences cannot be recognized better than word pairs or general nouns based on familiarity strength alone. All types of stimuli in Experiment 1 and Experiment 4 in the baseline condition were presented once, so the familiarity strength was not a factor in recognition hits. In fact, the distinctiveness of picture pairs and specific subject nouns in terms of their unique specific encoding may engender higher recognition hits compared to counterparts (i.e. word pairs and general subject nouns). Moreover, the non-mirror pattern replicates Hockley (2008) finding of picture superiority effect. Indeed, Hockley (2008) stated his finding of a picture superiority effect was compatible with Xu and Malmberg's (2007) dual-process model if it is assumed that picture pairs are better encoded than word pairs, but the effectiveness of recall-to-reject is similar for both types of pairs.

Thirdly, interference eliminated the recognition hit rate advantage for picture pairs and specific nouns in the baseline condition. Single process theorists would not be able to explain this phenomenon since the hit rate advantage in the baseline condition according to single process theorists was due to pictures and specific nouns being more familiar than their counterparts. Indeed, dual process theorists would be able to explain this phenomenon. Picture pairs and specific nouns share a hit rate advantage in baseline condition, because are more distinctive than their counterparts. In a sense, picture pairs and specific nouns share a more specific encoding and so are retrieved in memory partly due to recollection. Indeed, according to

dual-process theorists recollection is described as a search for specific information, a process similar to that involved in a recall task (Humphreys, 1978) Moreover, due to interference or item familiarity, picture pairs and specific nouns became less distinctive in memory and so are recognized at a similar rate as their counterparts In effect the memorial advantage of distinctiveness can be eliminated through interference

Fourthly, it is clear from the current study that the remember/know procedure is not an ideal procedure for distinguishing recollection versus familiarity-based recognition decisions An exact pattern for the effects of interference on remember responses and IRK responses in accordance with the dual process theory was not found In accordance with Dual process theory, for both Experiment 1 and Experiment 4, IRK hits and IRK false alarms increased with interference Contrary to the predictions of the dual process view, the proportion of remember responses for hits and false alarms did not decrease with interference However, as expected remember false alarm rates, IRK hit rates and IRK false alarms consistently increased with interference Therefore, this pattern of results from the remember and know procedure, suggests that the remember and know procedure is not an ideal procedure for distinguishing recollection versus familiarity in recognition decisions Another way to measure the contribution of recollection and familiarity to recognition memory is the Receiver operating characteristic (ROC) (Yonelinas, 2002) The participant rates the confidence of their recognition memory responses usually on a scale of 1 to 5 (1 = very unsure to very sure) By plotting hits versus false alarms as a function of confidence a curve is drawn Using mathematical algorithms, familiarity and recollection estimates are derived based on the idea that recollection is a threshold process and familiarity follows a signal-detection process



## *Conclusion*

The current study provides four new important findings to research in associative recognition memory. Firstly, distinctiveness plays an important role in associative memory as it does in item memory. Secondly, the picture superiority effect is likely an effect of unique encoding since the same pattern of results was found for specific nouns which were specific instantiations of general nouns. Thirdly, the memorial advantage of distinctiveness can be eliminated through interference. The overall pattern of the results of the current study is more consistent with a dual process theory than for single process theory.

## *Future Research Directions*

There are certainly weaknesses in the current study which must be addressed in future research studies in order to provide further support for the dual process theory of recognition memory and the idea that item distinctiveness in associative recognition paradigm can be removed through familiarization. Firstly, the experiments in the current study must also include other types of visual stimuli such as Chinese characters, faces, vivid pictures (i.e. photographs of objects) in order to examine the effects of interference. How would interference affect the associative recognition of these stimuli compared to picture pairs (i.e. line drawings)? What about pictures which are emotional in nature how does associative information differ with neutral information? Secondly, the findings of Experiment 4 showed that the type of subject noun (i.e. specific or general) encoded in sentence determined recognition accuracy. It should be noted the specific noun was an instantiation of the general subject noun. However, there are more questions to consider for Experiment 4. How would associative recognition differ for specific and general subject nouns encoded in longer sentences? These questions need to be answered since questions regarding how reading comprehension can be improved will be

answered. An EEG study is necessary in order to examine the time sequence and brain areas involved in retrieval from memory of specific nouns which are instantiations of general nouns.

Thirdly, further studies are required to examine the effects of manipulating item familiarity and associative familiarity on associative recognition. The finding of an increase in item familiarity due to interference eliminating the memorial advantage of distinctiveness of picture pairs and specific sentence should be extended to other more distinctive stimuli such as faces, vivid pictures (i.e. photographs of objects). An fMRI study would be helpful in determining how distinctiveness of stimuli (i.e. picture pairs or specific nouns) is reduced with interference, by examination of activation of brain areas both in the baseline and interference conditions. Indeed some researchers using fMRI have determined from encoding activation of perirhinal cortex as responsible for item familiarity, whereas encoding activation in the hippocampus as responsible for source recollection (Davachi, Mitchell & Wagner, 2003). Although, recently Wixted & Squire (2010) based on a review of neuroimaging research studies using the remember and know procedure, have suggested the hippocampus may be involved in both recollection and familiarity retrieval processes, because know responses may be associated with lesser degrees of recollection.

Fourthly, would the effects of familiarization on distinctive stimuli be similar for familiarization of stimuli encoded in distinctive contexts? Consequently, it is necessary to examine if there are age differences. Indeed, older adults have more difficulty than younger adults in recollecting contexts in which an item was presented (Ferguson, Hashtroudi, & Johnson, 1992, Naveh-Benjamin & Craik, 1995). Some researchers have suggested this difficulty lies in older adults' inability to spontaneously engage in processes at study required for recollection at retrieval (Skinner & Fernandes, 2008). Further neuroimaging studies are required.

in the investigation of the familiarization effect on distinctive stimuli in older adults, patients with Alzheimer's and other memory disorders

Lastly, one important question not clearly studied in the current study, is the question what decision processes the participant is going through when providing the remember and know responses in the baseline and interference conditions. Understanding what decision processes the participant is going through when making remember and know decisions may answer the question of why the remember and know is not an ideal procedure for distinguishing recollection versus familiarity-based recognition decisions in the current study? Confidence judgments would have been included in this regard in order for Receiver operating characteristic (i.e. ROC) curves to be shown. Further investigation into finding a more suitable procedure for distinguishing recollection versus familiarity-based recognition decisions will also be helpful in evaluating eye witness testimony.

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## Tables

**Table 1**

Degree of Match between Probes and Memory

Test Probe	Type	Condition	Items in Memory									
			A-B	A-C	A-D	A-E	F-B	F-C	F-D	F-E	G-H	I-J
A-B	Studied	Interference	I	P	P	P	M	M	M	M	M	M
G-H	Studied	Baseline	M	M	M	M	M	M	M	M	I	M
A-H	Rearranged	Interference	P	P	P	P	P	M	M	M	M	M
G-I	Rearranged	Baseline	M	M	M	M	M	M	M	M	P	P

Note Similar to Verde (2004), the degree of match between a recognition probe and an item in memory can be described as identical (I), a partial match (P), or a mismatch (M), with I>P>M

**Table 2**

*Experiment 1 Mean Hits and False Alarms for each stimulus type in baseline and interference conditions of the recognition memory experiment*

<b>Judgment</b>	<b>HR-B</b>	<b>SE</b>	<b>HR-I</b>	<b>SE</b>	<b>FA-B</b>	<b>SE</b>	<b>FA-I</b>	<b>SE</b>	<b>HR-FAR (base line)</b>	<b>SE</b>	<b>HR-FAR (interference)</b>	<b>SE</b>
Recognition WW	59	04	73	04	21	03	61	05	38	04	12	05
Recognition PP	72	03	78	04	21	03	58	08	51	05	20	05
Remember WW	38	05	40	05	11	02	29	06	17	06	11	06
Remember PP	45	06	41	04	07	02	28	03	24	07	14	06
Know WW	21	38	33	05	10	03	61	05	11	05	01	04
Know PP	27	06	37	05	14	03	31	04	13	07	06	05
IRK WW	31	05	50	05	11	02	67	25	20	06	- 16	23
IRK PP	37	06	63	05	15	03	42	05	23	07	21	07

**Note:** Mean Hit Rates (HR), False Alarm Rates (FAR) for the Intact and Rearranged Word (WW) and Picture (PP) Pair Tests in the baseline (B) and interference (I) conditions of Experiment 1 Note stimuli are between subjects

**Table 3**

*Experiment 2 Hits, False alarms and Correct Recognition scores for each stimulus type in familiar and non-familiar conditions of the recognition memory experiment*

<b>Judgment</b>	<b>Hits</b>	<b>SE</b>	<b>FA</b>	<b>SE</b>	<b>HR-FAR</b>	<b>SE</b>
WW Familiar	0.769	0.027	0.193	0.034	0.578	0.053
WW Non-familiar	0.741	0.028	0.172	0.024	0.556	0.040
PP Familiar	0.863	0.024	0.162	0.023	0.701	0.040
PP Non-familiar	0.785	0.031	0.241	0.025	0.558	0.045

Note Mean Hit Rates (HR), False Alarm Rates (FAR), Corrected Rejection Scores for the Intact and Rearranged Word and Picture Pairs in Familiar and non-familiar conditions

**Table 4**

*Experiment 2 Mean response times in milliseconds for each stimulus type in familiar and non-familiar conditions of the recognition memory experiment*

<b>Judgment</b>	<b>Hits</b>	<b>SE</b>	<b>Correct rejections</b>	<b>SE</b>
WW Familiar	2982	614.9	2653	142.4
WW Non-familiar	2237	711.9	2649	132.1
PP Familiar	1720	84.09	2105	90.7
PP Non-familiar	1928	110.6	2331	129.5

Note Mean reaction times for Hit Rates (HR) and False Alarm Rates (FAR) for the Intact and Rearranged Word and Picture Pairs in Familiar and non-familiar conditions

**Table 5**

*Experiment 3 Mean hits, false alarms and correct recognition scores for each stimulus type in familiar and non-familiar conditions of the recognition memory experiment*

<b>Judgment</b>	<b>Hits</b>	<b>SE</b>	<b>FA</b>	<b>SE</b>	<b>HR-FAR</b>
WW Familiar	0.79	0.02	0.22	0.03	0.57
WW Non-familiar	0.71	0.02	0.19	0.02	0.53
PP Familiar	0.81	0.02	0.20	0.03	0.61
PP Non-familiar	0.78	0.03	0.18	0.02	0.60

Note Mean Hit Rates and Corrected Rejection Scores for the Intact and Rearranged Word and Picture Pairs in Familiar and non-familiar conditions

**Table 6**

*Experiment 3 Mean response times in milliseconds for each stimulus type in familiar and non-familiar conditions of the recognition memory experiment*

<b>Judgment</b>	<b>Hits</b>	<b>SE</b>	<b>Correct Rejections</b>	<b>SE</b>
WW Familiar	1780	72 31	2427	103 5
WW Non-familiar	2156	126 9	2296	95 1
PP Familiar	1667	68 96	2518	264 3
PP Non-familiar	1752	67 06	2130	99 66

Note Mean reaction times for Hit Rates and Correct Rejections for the Intact and Rearranged Word and Picture Pairs in Familiar and non-familiar conditions

**Table 7**

*Experiment 4 Mean Hits and False Alarms for each stimulus type in baseline and interference conditions of the recognition memory experiment*

<b>Judgment: Word pairs</b>	<b>HR-B</b>	<b>SE</b>	<b>HR-I</b>	<b>SE</b>	<b>FA-B</b>	<b>SE</b>	<b>FA-I</b>	<b>SE</b>	<b>HRB- FARB</b>	<b>SE</b>	<b>HRI- FAI</b>	<b>SE</b>
Recognition General	68	03	77	04	21	03	53	04	47	04	24	04
Recognition Specific	77	03	80	03	23	03	64	04	54	03	16	05
Remember General	51	05	46	04	08	02	26	04	43	05	20	04
Remember Specific	54	05	53	05	08	02	31	05	46	05	23	05
Know General	17	04	31	04	13	02	27	03	04	04	03	03
Know Specific	22	05	27	04	15	02	22	04	07	05	- 07	03
IRK General	29	04	56	08	14	02	36	05	15	04	20	06
IRK Specific	44	06	54	05	17	03	48	05	27	06	06	04

Note Mean Hit Rates (HR), False Alarm Rates (FAR), Corrected rejection scores and the Standard Errors of the Means (SE), for the Intact and Rearranged General noun and Specific noun Tests of Experiment 4



## Appendix 1

***Study instructions for Experiment 1:*** for picture condition (if participant in word condition, only the words pictures and picture were replaced by words)

You will be presented with a list of pairs of pictures. The pairs will be presented one pair at a time in the centre of the computer screen.

Please try to make an association between the pictures in each pair so that you will be able to remember which pictures were paired with which pictures. You can try forming a mental image involving both pictures or generating a sentence that involves both pictures to make it easier for you to remember the pictures later.

Your memory for the pairs of pictures will be tested in the second half of the experiment.

Press the space key to begin.

***Test instructions for Experiment 1:*** Word or Picture conditions

Please wait for the Experimenter to provide you with test instructions.

Test instructions provided by Experimenter on sheet.

### **Instructions for test phase:**

During the recognition test, you will see a list of word pairs.

Half of the test pairs are old or intact pairs. The two words of the old pairs were shown together in the study list.

The other half of the test pairs are new or rearranged pairs. The two words of the new pairs were presented in the study list, but they were presented in two different study pairs. That is, they were not shown together in one pair at study.

For each test pair, please try to decide if the pair of words is an old (intact) or new (rearranged) pair.

Ex: study word pair: house woman

Ex: test word pair (intact): house woman –old? –familiar or remember?

Ex: test word pair (rearranged): house car or car house –new? –familiar or remember?

You may decide that a pair is old because you can remember or specifically recall that one word was presented with the other word. Or you may decide that a pair is new pair because you can remember or specifically recall that one word of the test pair was shown with a different word at study. In either case, your old or new decision is based on specifically remembering what word was presented with what word at study.

Alternatively, you may decide that a pair is an old pair because you have a strong sense of familiarity associated with the two words even though you cannot specifically recall the two words being presented together. Or, you may decide that a pair is a new pair because you do not have a feeling of familiarity associated with the two words. In these instances, your old or new decision is based on your feeling of familiarity associated with the two words (and not on specifically remembering that the two words were or were not shown together).

**Please press one of the four following keys indicate your recognition decision for each test pair**

**1.** Press the "," key to indicate that the two items in the test pair were presented together in the study list (i.e., **an old pair**) based on your feeling that the **pair is very familiar** although you cannot specifically remember that the two words were shown together at study.

**2.** Press the "/" key to indicate that the two items in the test pair were presented together in the study list (i.e., **an old pair**) and you can **specifically remember that the two words were shown together.**

**3.** Press the "z" key to indicate that the two items in the test pair were not presented in the study list (i.e., **a new pair**) based on your feeling that the **pair is not very familiar**.

**4.** Press the "c" key to indicate that two items in the test pair were not presented in the study list (i.e., **a new pair**) and you know this because you can **specifically remember that one or both of the words were presented with different words at study**.

## Appendix 2

***Study instructions for Experiment 2:*** for picture condition (if participant in word condition, only the words pictures and picture were replaced by words)

### *Study Phase 1*

You will see pictures presented once at a time to study Please press the space bar to continue

### *Study Phase 2*

You will be presented with a list of pairs of pictures The pairs will be presented one pair at a time in the centre of the computer screen

Please try to make an association between the pictures in each pair so that you will be able to remember which pictures were paired with which pictures Your memory for the pairs of pictures will be tested in the second half of the experiment

### *Test phase*

Please wait for the Experimenter to provide You with test instructions

### **Instructions for test phase:**

During the recognition test, you will see a list of picture pairs

**Half of the test pairs are old or intact pairs** *The two pictures or words of the old pairs were shown together in the study list*

**The other half of the test pairs are new or rearranged pairs** *The two pictures or words of the new pairs were presented in the study list, but they were presented in two different study pairs That is, they were not shown together in one pair at study*

For each test pair, please try to decide if the pair of pictures or pair of words is an old (intact) or new (rearranged) pair

Ex study picture pair word pair house woman

Ex test picture pair or word pair (intact) house woman –old?

Ex test picture pair or word pair (rearranged) house car or car house -new?

Please **press one of the four following keys to indicate your recognition decision for each test pair**

2 Press the "/" key to indicate that the two items in the test pair were presented together in the study list (i.e., **an old pair**)

3 Press the "z" key to indicate that the two items in the test pair were not presented in the study list (i.e., **a new pair**)

### **Appendix 3**

#### ***Study instructions for Experiment 4:***

##### *General condition*

You will be presented with a list of pairs of words (i.e. Noun and Location) embedded in sentences. The sentences containing the pairs will be presented one pair at a time in the centre of the computer screen.

For example: The “Man” is in the “Museum”

Please try to make an association between the words in each pair in the sentence so that you will be able to remember which words were paired with which words.

Your memory for the pairs of words in the sentences will be tested in the second half of the experiment.

Press the space key to begin.

##### *Specific condition*

You will be presented with a list of pairs of words (i.e. Noun and Location) embedded in sentences. The sentences containing the pairs will be presented one pair at a time in the centre of the computer screen.

For example: The “Scientist” is in the “Museum”

Please try to make an association between the words in each pair in the sentence so that you will be able to remember which words were paired with which words.

Your memory for the pairs of words in the sentences will be tested in the second half of the experiment.

Press the space key to begin.

#### ***Test instructions for Experiment 4:***

You will now decide whether each word pair was on the list of word pairs that you studied by selecting one of four choices.

Please take a moment to read over the test instructions provided to You by the experimenter.

Press the space key to continue.

*For General condition*

**Instructions for test phase:**

For each test pair, please try to decide if the pair of words (i.e. nouns) in the sentence is an old (intact) or new (rearranged) pair

Ex study word pair in sentence The Man is in the Museum

Ex test word pair (intact) The Man is in the Museum  
-old? -familiar or remember?

Ex test word pair (rearranged) The Car is in the Museum  
-new? -familiar or remember?

You may decide that a pair in a sentence is old because you can remember or specifically recall that one word was presented with the other word

Or you may decide that a pair in a sentence is a new pair because you can remember or specifically recall that one word of the test pair was shown with a different word at study. In either case, your old or new decision is based on specifically remembering what word was presented with what word in the sentence at study

Alternatively, you may decide that a pair is an old pair because you have a strong sense of familiarity associated with the two words even though you cannot specifically recall the two words being presented together

Or, you may decide that a pair is a new pair because you do not have a feeling of familiarity associated with the two words. In these instances, your old or new decision is based on your feeling of familiarity associated with the two words (and not on specifically remembering that the two words were or were not shown together)

Please **press one of the four following keys to indicate your recognition decision for each test pair**

1. Press the "," key to indicate that the two items in the test pair were presented together in the study list (i.e., **an old pair**) based on your feeling that the **pair is very familiar** although you cannot specifically remember that the two words were shown together at study in a sentence

2. Press the "/" key to indicate that the two items in the test pair were presented together in the study list (i.e., **an old pair**) and **you can specifically remember that the two words were shown together in a sentence.**

3. Press the "z" key to indicate that the two items in the test pair were not presented in the study list (i.e., **a new pair**) based on your feeling that the **pair is not very familiar**

4. Press the "c" key to indicate that two items in the test pair were not presented in the study list (i.e., **a new pair**) and you know this because **you can specifically remember that one or both of the words were presented with different words at study in a sentence**

*For Specific condition*

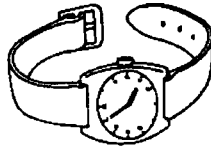
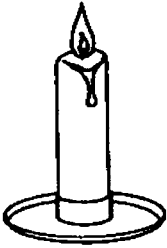
There were similar test instructions as General condition. Only difference being in the examples, the general word "Man" was replaced by "Scientist" And the general word "Car" was replaced by "Mercedes"

## Appendix 4

### *Sample stimuli presented in Experiment 1*

<b>Study (Words or Pictures from Baseline and Interference condition were studied together in one study list)</b>		
<b>Baseline</b>		
1	Candle	Watch
2	Tree	Sock
3	Leaf	Trumpet
4	Giraffe	Microscope
5	Umbrella	Cup
6	Shoe	Stove
7	turtle	Ball
8	Mop	Razor
9	Feather	Telephone
<b>Interference</b>		
1	cake	helicopter
2	cake	cactus
3	cake	sailboat
4	cake	mirror
5	suitcase	helicopter
6	suitcase	cactus
7	suitcase	sailboat
8	suitcase	mirror
<b>Test</b>		
Intact 1	giraffe	microscope
2	cake	sailboat
3	shoe	stove
4	suitcase	mirror
5	cake	helicopter
Rearranged 1	cake	butterfly
2	suitcase	bus
3	giraffe	log
4	shoe	bucket

Sample Picture Pair presented at Study



Sample Word pair presented at Study

Candle

Watch



## Appendix 5

### *Sample stimuli presented in Experiment 2*

<b>Study (words and word pairs/pictures and picture pairs randomly presented)</b>						
<b>Study list 1 (Familiar)</b>						
1	candle	6	necklace	11	cake	
2	tree	7	cup	12	screwdriver	
3	leaf	8	stove	13	sock	
4	book	9	telephone	14	trumpet	
5	wallet	10	Spoon	15	lighthouse	
<b>Study list 2 (Familiar and unfamiliar pairs)</b>						
1	candle	watch	familiar	7	firehydrant	bucket non-familiar
2	tree	sock	familiar	8	cane	drum non-familiar
3	leaf	trumpet	familiar	9	bee	vacuum non-familiar
4	book	spoon	familiar	10	peanut	lock non-familiar
5	wallet	airplane	familiar	11	camel	bread non-familiar
6	lighthouse	corn	familiar			
<b>Test (word pairs or picture pairs randomly presented)</b>						
<b>Intact</b>	1	candle	watch	Familiar		
	2	cane	drum	Non-familiar		
	3	peanut	lock	Non-familiar		
	4	wallet	airplane	Familiar		
<b>Rearranged</b>	1	lighthouse	log	Familiar		
	2	pineapple	pipe	Familiar		
	3	windmill	bread	Non-familiar		
	4	camel	pumpkin	Non-familiar		
	5	crown	telescope	Familiar		

## Appendix 6

### *Sample stimuli presented Experiment 3*

<b>Study (words and word pairs randomly presented)</b>						
<b>Study list 1 (Words repeated threetimes, Familiar)</b>						
1 candle	6 wallet	11 tree	16 leaf			
2 tree	7 tree	12 candle	17 book			
3 candle	8 wallet	13 wallet	18 airplane			
4 tree	9 airplane	14 airplane	19 book			
5 candle	10 wallet	15 book	20 airplane			
<b>Study list 2 (Familiar and unfamiliar pairs)</b>						
1 candle	watch	familiar	7 firehydrant	bucket	non-familiar	
2 tree	sock	familiar	8 cane	drum	non-familiar	
3 leaf	trumpet	familiar	9 bee	vacuum	non-familiar	
4 book	spoon	familiar	10 peanut	lock	non-familiar	
5 wallet	airplane	familiar	11 camel	bread	non-familiar	
6 lighthouse	corn	familiar				
<b>Test</b>						
<b>Intact</b>	1 candle	watch				Familiar
	2 cane	drum				Non-familiar
	3 peanut	lock				Non-familiar
	4 wallet	airplane				Familiar
<b>Rearranged</b>	1 lighthouse	log				Familiar
	2 pineapple	pipe				Familiar
	3 windmill	bread				Non-familiar
	4 camel	pumpkin				Non-familiar
	5 crown	telescope				Familiar

## Appendix 7

*Sample stimuli presented in Experiment 4*

**Study: Baseline and Interference conditions were in one study list**

<b>Baseline:</b>
<b>List of general sentences:</b> The criminal is in the laundry The boy is in the warehouse The furniture is in the jungle
<b>List of specific sentences:</b> The robber is in the laundry The paperboy is in the warehouse The desk is in the jungle
<b>Interference:</b>
<b>List of general sentences:</b> The metal is in the cavern The metal is in the gymnasium The metal is in the embassy The metal is in the ditch The academic is in the cavern The academic is in the gymnasium The academic is in the embassy The academic is in the ditch The money is in the cavern The money is in the gymnasium The money is in the embassy The money is in the ditch The alcohol is in the cavern The alcohol is in the gymnasium The alcohol is in the embassy The alcohol is in the ditch
<b>List of specific sentences:</b> The copper is in the cavern The copper is in the gymnasium The copper is in the embassy

The copper is in the ditch  
The chemist is in the cavern  
The chemist is in the gymnasium  
The chemist is in the embassy  
The chemist is in the ditch  
The dime is in the cavern  
The dime is in the gymnasium  
The dime is in the embassy  
The dime is in the ditch  
The whiskey is in the cavern  
The whiskey is in the gymnasium  
The whiskey is in the embassy  
The whiskey is in the ditch

**Test:**

**General**

**Intact pairs:**

The criminal is in the laundry

**Rearranged pairs:**

The criminal is in the gymnasium

**Specific**

**Intact pairs:**

The robber is in the laundry

**Rearranged pairs:**

The robber is in the gymnasium