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Context Effects on Recognition Memory for Words

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ABSTRACT. The present study examined whether word frequency, study context, and word repetition produce differences in word recognition and context recognition. We also tested a prediction of the dual process model where recognition memory has two individual processes, namely recollection and familiarity. Participants studied lists of words presented in contexts defined by background color, screen position of the word, and study question during encoding. Word frequency, study context, and word repetition were manipulated during the encoding phase. During the subsequent retrieval phase, participants performed two memory tasks: a word recognition task involving *old judgments* or *new judgments* and a context recognition task involving *remember judgments* and *know judgments* for words reported as an old judgment. We found effects of each of the manipulated factors on recognition memory. False alarms were higher for common words than uncommon words (η^2_p = .38, p < .001). Repeated words were remembered better than nonrepeated words (η^2_p = .76, p < .001). Words repeated across contexts during the study were recognized better than words repeated in the same context during encoding (η^2_p = .18, p = .03). We also found effects of repetition and word frequency on reaction time. Repeated words were recognized faster than nonrepeated words (η^2_p = .23, p = .01), and uncommon words were recognized faster than common words (η^2_p = .38, p = .001). However, we did not find evidence to support the dual process model's predictions about the impact of context on remember and know judgments.

Keywords: recognition memory, word frequency, repetition, context, dual process model

The process by which different kinds of information are encoded and retrieved by memory is still unclear, despite the current knowledge of distinct memory systems (Murnane, Phelps, & Malmberg, 1999; Oberauer, 2018). The *dual process model* of recognition memory states that two separate processes govern recognition: familiarity and recollection (Norman & O'Reilly, 2003; Opitz, 2010; Rugg & Yonelinas, 2003). Familiarity involves recognizing a piece of information or stimulus without accessing other information about the context in which the material was learned (Opitz, 2010). Recollection involves retrieving all the information about the stimulus and the context in which it was presented (Opitz, 2010). The dual process model of recognition shows the complexity of recognition memory and the retrieval process (Jacoby & Dallas, 1981; Mulligan, Smith, & Spataro, 2016; Murnane, Phelps, & Malmberg, 1999).

This study replicates and extends an experiment that tested the dual process model's predictions about the influence of context and repetition on recognition memory (Opitz, 2010). Our study replicates the behavioral portion of that study's methodology, which measured reaction time and accuracy, and extends the previous work to examine the influence of word frequency on

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recognition memory. Thus, this study has the potential to provide further evidence of the importance of context and repetition, while adding to the literature on how word frequency impacts memory.

Repetition, Context, and Word Frequency

Repeated presentations of a stimulus tend to improve memory encoding (Xue et al., 2010). When the conditions of encoding match each other across encoding sessions, similar patterns of neural activity associated with the episodic memory of the event are evoked. For example, an fMRI study of activation in cortical areas associated with object recognition and memory encoding showed similar patterns of activity across encoding trials for items that were subsequently recognized (Xue et al., 2010). However, simple repetition of materials does not have a significant influence on memory recall (Karpicke, 2012; Tulving, 1966) or recognition (Jacoby & Dallas, 1981). Contemporary researchers of memory have connected the depth of processing one uses to encode information with subsequent retrieval for the information (Baddeley & Hitch, 2017). For example, thinking about how you would use an item to survive on a desert island produces better free recall for the item than thinking about how pleasant it is (Nairne, Thompson, & Pandeirada, 2007).

Furthermore, memory is better when the context during an encoding phase matches the context during retrieval than when there is a mismatch between encoding and retrieval conditions (Godden & Baddeley, 1975). Context refers to the details of the surrounding environment in which information is learned or experienced. Contextual information can include low-level visual or auditory features such as background display (Chun, 2000), the visual position of a stimulus (Hollingworth, 2006), or background music (Coutinho & Scherer, 2017). It can also encompass higher-level features (i.e., features that rely on knowledge or previous experience) such as the emotional context of a scene (Finke, Zhang, Best, Lass-Hennemann, & Schächinger, 2018) or the entirety of the physical environment (Godden & Baddeley, 1975). The effects of contextual congruence can also occur when a study participant is unaware of the congruence (Chun, 2000; Jiang & Sisk, 2019). Chun and Jiang (2003) compared visual searches for letters on displays that appeared only once during the course of the experiment and displays shown several times during the course of the experiment. Letters on these repeated displays always appeared in the same location. Chun and Jiang showed that, although all visual searches got faster over the course of the experiment, searches were faster for items on the repeated displays. Furthermore, fewer than half of participants reported noticing the repeated displays.

Although memory research has emphasized the importance of repetition and context, the effects of word frequency (i.e., how often an English word occurs in written and spoken language) are less clear. Word frequency has a significant effect on word recognition tasks (Brysbaert & New, 2009). In a lexical decision task, where a participant is shown a string of letters and asked to decide whether the letter string forms an English word, high frequency words are evaluated faster than low frequency words (Balota & Chumbley, 1984). This suggests easier lexical access to common words. However, word frequency has no significant effect on reaction time in tasks such as category verification (Andrews, 1992). Thus, there seem to be inconsistent effects of word frequency on different types of memory tasks.

Dual Process Model of Recognition Memory

The process of familiarity and recollection of the dual process model, which we introduced earlier, are suggested to retrieve different kinds of information regarding a stimulus, where familiarity may be more characteristic of semantic memory and recollection is characteristic of episodic memory (Henson & Gagnepain, 2010; Oberauer, 2018). Some studies have proposed that familiarity is an automatic process whereas recollection is a controlled process (Jacoby, 1991; Oberauer, 2018; Yonelinas & Jacoby, 1995). Although there has not been consensus on a dual process or single process model, there is evidence that one distinct form of information can be retrieved without the other (Henson & Gagnepain, 2010; Jacoby, 1991; Oberauer, 2018; Opitz, 2010).

The dual process model of recognition memory makes predictions about how context and repetition impact memory for words. First, the dual process model predicts that participants should respond differently depending on whether words are learned within the same context or in different contexts. Secondly, the model proposes that presenting a word in the same context multiple times facilitates stimulus binding, which associates a word with the contextual features that occurred during its presentation. The model predicts less stimulus binding when words are presented across contexts. Thus, the model predicts better memory for words presented in the same context at testing as encoding, as well as better memory for repeated words than non-repeated words.

Stimulus binding can be tested by asking participants to make *remember judgments* and *know judgments* about words presented during the encoding phase. Remembering entails retrieving the contextual features in which a word appeared, while knowing does not. For example, if participants indicate that they remember the word in its context, as part of the recollection process, this corresponds to higher stimulus context binding, which is most likely to occur with words repeatedly presented in a single context (Norman & O'Reilly, 2003; Opitz, 2010). However, if participants indicate only knowing the word and not the contextual features in which it was presented, as part of the familiarity process, this would reflect lower stimulus context binding, which is likely to occur with words presented across all three contexts (Norman & O'Reilly, 2003; Opitz, 2010).

Opitz (2010) tested the dual process model by examining recognition memory for pictures in different colored backgrounds and screen positions. During the learning phase of the study, several contextual features were manipulated: the number of presentations, position on the screen, screen background, and the encoding task question presented after a picture. The repeated pictures in this learning phase were divided into two groups: one group of pictures was repeated with the same contextual features and the other was repeated using multiple contextual features. During the retrieval phase, participants were asked to recognize which pictures they had seen before and whether they could remember seeing them in their context or merely knew that they had seen them before.

Opitz (2010) collected both behavioral data and physiological data, using event-related potentials, to determine the independence of familiarity and recollection processes. He found that repeated pictures were recognized faster than nonrepeated pictures, and participants were best at recognizing repeated pictures that occurred across different contexts and worst at recognizing pictures presented only once. In addition, remember and know judgments elicited different event-related potentials. Specifically, remember judgments elicited stronger late responses (550–770 ms after stimulus presentation) in parietal recording sites than know judgments did. These results lend further support to the dual process model's proposal that recollection and familiarity are independent processes.

Present Study

The current study expanded on the Opitz (2010) study in two ways. First, it examined memory for words rather than pictures. Second, the study examined whether word frequency affects recognition under repetition and context manipulations. The study evaluated four research questions about recognition memory: (a) are the reaction times faster for words when they are repeated than when presented once?, (b) is the number of correct responses greater for repeated words than nonrepeated words?, (c) are there differences in recognition for common and uncommon words?, and (d) are the know judgments greater for words presented across contexts and are the remember judgments greater for words presented within the same contexts?

We predicted that our experimental manipulations involving repetition, word frequency, and context would affect accuracy, reaction time, and remember/know judgments during recognition. We predicted greater accuracy (i.e., higher hit rates and lower false alarm rates) for words repeated three times compared to single presentations, as well as lower reaction times and greater accuracy for common words than uncommon words. We also predicted that know and remember judgments would differ based on within- and across-context presentations. Specifically, in line with the dual process model of recognition, we predicted a greater number of know judgments for words presented across different contexts during encoding and a greater number of remember judgments for words always presented in the same context during encoding.

Method

Participants

This study represents a replication with extension of the experiment described in Opitz (2010). Thus, we used the data reported in that article to estimate the required sample size for the current study. Because Opitz (2010) did not report effect sizes, we first used their reported *F*-statistic values and degrees of freedom values to calculate effect sizes for the reported statistical tests. The smallest of these effect sizes (for the hypothesis test comparing recognition across contexts versus within contexts) was $\eta^2_p = .33$. A power analysis using G*Power (Faul, Erdfelder, Lang, and Buchner, 2007) revealed that detecting a difference between two means for a within-groups design using $\alpha = .05$, $\beta = .20$ and nonsphercity correction $\varepsilon = 1$ would require data from 19 participants.

A total of 26 participants completed the experiment. All participants were recruited from Tennessee State University campus through recruitment presentations in classrooms, recruitment across the campus, and through the SONA system, which is the subject pool management system of the university's psychology department. Each participant was 18 years or older and enrolled as a student. One participant was excluded for not meeting the age criteria. Another participant had to be eliminated from the analysis because the data collection program did not record the participant's reaction time data. The average age of the remaining 24 participants was 20.91 years (age range: 18–38, $SD = 4.28$), and 17 of the participants were women. The students reported normal color vision and no light sensitivity. The students received extra credit for select courses for participation in the study. However, the extra credit offered for participation was only one of several extra credit opportunities that were available for the course so that participation in the study was not required for success in the course.

Materials

The stimuli were presented on an iMac with a 21.5-inch monitor with a display resolution of 1920 x 1080 pixels. We presented the experiment and collected the data using the Psychophysics Toolbox for MATLAB (Brainard, 1997; Kleiner, Brainard, Pelli, 2007; Pelli, 1997).

The study used six lists of 42 words. We chose equal numbers of common and uncommon words from the Kučera and Francis written frequency scale, which measures word occurrences per million words (MRC, n.d.). All words had four to seven letters. The words were comprised of nouns, adjectives, and verbs as distinguished in the Medical Research Council Psycholinguistic Database. The words were not restricted to any single category to get enough unique uncommon and common list of words to use in the study that could be associated with each of the task questions. For each task question, approximately half of the words required a "yes" response. The uncommon words (e.g., herring, benzene, cowhide, belfry, frown) had a mean Kučera and Francis frequency of 1.39 and a range of 1 to 3, and the common words (e.g., rifle, green, market, paper, writing) had a mean frequency of 147.07 and a range of 60 to 400. The concreteness and imageability of the words were between the scale of 1 and 7 as determined by the Medical Research Council Psycholinguistic Database.

The encoding and retrieval phases of the experiment were presented on varying background colors. The colors and RGB values are as follows: dark grey (RGB: 64, 64, 64), black (RGB: 0, 0, 0), white (RGB: 255, 255, 255), light grey (RGB: 128, 128, 128), and red (RGB: 255, 0, 0). In the encoding phase, the words were presented at different positions on the screen aside from the center. The positions were left side of the screen, which was approximately 27° of visual angle to the left of the fixation point, and the right side of the screen, which was approximately 27° of visual angle to the right of the fixation point at a viewing distance of approximately 18 inches.

Design

The study used a 2 (frequency) x 2 (repetition) x 2 (context) experimental design to examine the effects of repetition of common and uncommon words in different contexts on recognition. The word frequency factor compared common and uncommon words, as indexed by the Kučera and Francis scale. The repetition factor had two levels: repeated words were presented three times during the encoding phase, whereas nonrepeated words were presented only once during the encoding phase. Study context referred to whether a word was presented in the same context each time it was presented during the encoding phase or whether it appeared across contexts during the encoding phase.

Procedure

The study was approved by Tennessee State University's Institutional Review Board. After which, participants were recruited. The participants were first given an oral briefing about the purpose of the study and then directed to read the required consent form. After obtaining consent, participants completed a demographic questionnaire that asked about age, birth sex, gender identity, handedness, and whether the participant has normal or corrected to normal vision, normal color vision, and no light sensitivity.

Next, participants began the experiment, which had two phases: an encoding phase, consisting of three blocks, and a retrieval phase comprised in a single block. All responses were recorded using a keyboard. The participants were made aware that they could take breaks in between blocks, if and as needed.

Encoding phase. In the encoding phase, all words presented within a block had the same combination of three contextual features: background color, screen position, and task question (see Figure 1). In one block, words were presented on the left side of the screen on a dark grey background, and participants were asked whether the item the word represented would fit inside a shoebox. In another block, words were presented on the right side of the screen on a black background, and participants were asked if the word was a noun. In the last block, words were presented at the center of the screen on a white background, and participants were asked if the item the word represented was a human creation. The three blocks were presented in a random order for each participant.

The words presented in the experiment were chosen from six lists of 42 words from the Kučera and Francis written frequency scale. The six lists were first divided into two sets of three lists each. For each participant, one set was chosen to be presented in the encoding phase, and the other set was presented as distractors in the retrieval phase. The assignment of each list as target or distractor was randomized for each participant.

We assigned words from the study lists to three blocks of trials to create different levels of repetition context. Words from the first list were only presented once during the encoding phase. To create a repetition-within-context level, one third of the words from the second list were presented three times within a particular block of the encoding phase (that is, in the same background color, at the same place on the screen, followed by the same encoding question). To create a repetition-across-contexts level, the words from the third list were presented once in each of the three blocks, so that they appeared once in each of the different contexts.

The words from the three lists chosen for the encoding phase amounted to 98 trials in each block. The 98 trials of a block were comprised of 14 words from List 1, which were presented once (14 trials), 14 words from List 2, which were presented three times (42 trials), and all 42 words of List 3, which were presented once (42 trials). Each block took approximately five minutes to complete. At the start of each block, participants were asked to indicate a "yes" or "no" response using two marked keys on the keyboard to the task questions associated with the combination. Each word in the encoding phase was presented for 500 ms. After each word, there was a 1000 ms interval before the participant was asked to answer the task question with a yes or no response.

Retrieval phase. In the retrieval phase, all words were presented at the center of the screen on a light grey background (see Figure 2). The words in the retrieval phase comprised of all the words from the set of three lists presented in the encoding phase (42 words from three lists, which add up to 126 words) and the remaining words from the set of three lists (42 words from three lists, which add up to 126 words), which functioned as the distractor words. All words were presented once in the retrieval phase. Thus, the retrieval phase comprised of a total of 252 trials that took approximately 25 minutes to complete.

The words were presented for 500 ms each. Participants were asked to make an *old judgment* or a *new judgment* after 1000 ms of word presentation, using two marked keys on the keyboard. An old response indicated that they recognized the word from the encoding phase and a new response indicated that they did not recognize the word from the encoding phase. If participants made an old judgment, an additional question appeared asking them to make a know judgment or remember judgment using two different marked keys on the

FIGURE 1

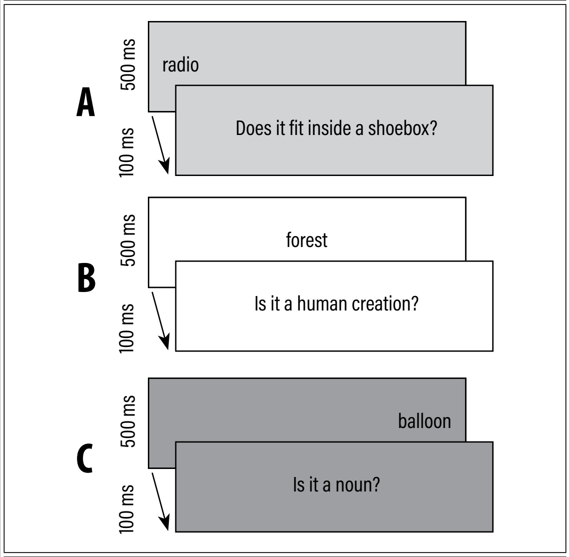

Figure 1. Illustration of the three blocks in the study phase, which consists of three combinations of the contextual features in each block. The contextual features are background colors (dark grey, white, and black), screen positions (left, center, and right), and task questions (Does it fit inside a shoebox? Is it a human creation? Is it a noun?). The words are presented for 500 ms, and the question appears after a 1000 ms interval. Note that the words are shown in white and black here for readability. During the experiment, words in all contexts were displayed using a red font.

keyboard. The remember judgment indicated that participants remembered the contextual features in which the words were presented, for example, left side or dark grey background. The know judgment indicated that participants remembered only the word and none of the other features.

Results

The data were analyzed to compare effects of word frequency, repetition, and contextual features on accuracy and speed of recognition. All responses and reaction times for old words and new words were analyzed for overall effects and word frequency effects. However, only the old words could be analyzed for repetition and context effects. The new words were only presented in the retrieval phase and thus could not be assessed for repetition and context effects, because these factors were manipulated in the encoding phase. The repeated-measures Analysis of Variance (ANOVA) was used for analysis of all conditions, and multiple comparisons were corrected using the Bonferroni correction.

Accuracy

To assess the accuracy of old responses, hit rates and false alarms were calculated and compared. Hit rate was defined as number of correct old responses for old words divided by the total number of old words. False alarm rate was defined as number of old responses to new words divided by the total number of new words. The data were also assessed for accuracy of new responses by comparing correct new response rate and false negative rate. Correct new response rate was all new responses to new words divided by the total number of new words, and false negative rate was all new responses to old words divided by all old words. The proportions for the above mentioned four conditions of responses are presented in Table 1. The average reaction times were assessed using these four response conditions as well (see Table 1).

Old and new responses had high accuracy rates. To assess the overall and word frequency effects on accuracy, hit rates from all context and repetition conditions were compared to the false alarm rates. A repeated-measures ANOVA conducted for hit rates and false alarms for uncommon and common words revealed a main effect of response type, $F(1, 23) = 204.40$, $p < .001$, $\eta^2_p = .89$, frequency, $F(1, 23) = 14.26$, $p = .001$, $\eta^2_p = .38$, and an interaction of response type and frequency, $F(1, 23) = 15.24$, $p = .001$, $\eta^2_p = .39$. For old words, the pairwise comparison revealed that hits ($M = 0.84$, 95% CI [.81, .89]) were greater than false alarms ($M = 0.21$, 95% CI [.11, .31]). The significant

FIGURE 2

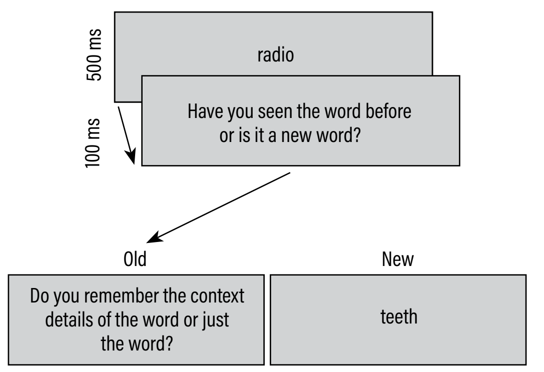

Figure 2. Simulation of a single trial in the test phase where words appeared at the center of the screen on a light grey background. The words are presented for 500 ms, and the question appears after a 1000 ms interval. A "yes" response to the question leads to another question. A "no" response to the question starts a new trial. Note that the words are shown in black here for readability. During the experiment, words in all contexts were displayed using a red font.

TABLE 1

Accuracy and Reacton Time Data

	Old Words						New Words		
	Overall	Frequency		Repetition			Overall	Frequency	
		Uncommon	Common	Single	Across Context	Within Context		Uncommon	Common
Proportions									
Old Repsonses	0.85(0.02)	0.85(0.05)	0.85(0.02)	0.73(0.03)	0.92(0.02)	0.89(0.02)	0.21(0.02	0.16(0.05)	0.26(0.05)
New Responses	0.79(0.05)	0.84(0.05)	0.74(0.05)	0.27(0.03)	0.08(0.02)	0.11(0.02)	0.15(0.02	0.15(0.02)	0.15(0.02)
Reaction Time									
Old Responses	443 (29.66)	396 (25.86)	489 (37.56)	503 (44.17)	402 (26.28)	441 (34.15)	609 (71.50)	565 (68.62)	624 (88.39)
New Responses	894 (102.44)	709 (97)	984 (126.84)	885 (130.57)	1036 (366.39)	1046 (137.02)	565 (48.50)	514 (50.50)	578 (49.09)

Note. Reaction times (ms) and mean proportions (+SEM) for old and new responses to old and new words.

interaction effect showed that common words were more likely to be false alarms than uncommon words, but common and uncommon words did not differ for hits. Figure 3 illustrates this interaction. Likewise, correct new responses (M = 0.79, 95% CI [.69, .89]) were higher than false negatives (M = 0.15, 95% CI [.11, .19]). The uncommon words were more accurately recognized as new words than common words, but uncommon and common words did not differ in the number of false negatives they produced.

Reaction times were lower for hits and correct new responses. The repeated-measures ANOVA for hit rates, false alarms, and word frequency showed a main effect of response type, $F(1, 23) = 9.15$, $p = .006$, $\eta^2_p = .28$, but no effect of frequency, $F(1, 23) = 1.95$, $p = .17$, $\eta^2_p = .07$, or interaction, $F(1, 23) = 0.11$, $p = .73$, $\eta^2_p = .001$. The pairwise comparisons showed that hits (M = 442ms, 95% CI [381, 504]) were recognized faster than false alarms (M = 594ms, 95% CI [467, 721]). The analysis was repeated for correct new responses, false negatives, and word frequency. The ANOVA revealed a main effect of response type, $F(1, 23) = 17.11$, $p < .001$, $\eta^2_p = .42$, but no effect of frequency, $F(1, 23) = 0.84$, $p = .36$, $\eta^2_p = .03$, or interaction, $F(1, 23) = 1.57$, $p = .22$, $\eta^2_p = .06$. The pairwise comparisons showed that correct new responses (M = 521 ms, 95% CI [448, 595]) were faster than false negatives (M = 805 ms, 95% CI [640, 970]). Thus, the correct responses for both old and new words were faster than incorrect responses.

Repetition and Context

To examine the effects of repetition, all old words were grouped into repeated and nonrepeated words. The context effects were analyzed by further classifying the repeated words into across-context and within-context. The proportions of hits and false negatives for all repeated and nonrepeated conditions, along with their reaction times, are presented in Table 1. However, an ANOVA was conducted for the grouped conditions using the hit rate. The false negatives were excluded from the analysis because participants were highly accurate in their new responses. The word frequency was also analyzed by subdividing all groups into uncommon and common words. The accuracy and reaction times of hit rates and word frequency were compared in all repetition and context groups.

Old words were recognized best when repeated across contexts. The ANOVA for repeated and nonrepeated words using hit rate as the dependent variable showed a significant main effect of repetition, $F(1, 23) = 74.05$, $p < .001$, $\eta^2_p = .76$, but no effect of word frequency, $F(1, 23) = 0.00$, $p = .98$, $\eta^2_p < .001$, or an interaction, $F(1, 23) = 0.02$, $p = .87$, $\eta^2_p = .001$. The pairwise comparison revealed that hit rates for repeated words (M = 0.90, 95% CI [.87, .94]) were higher than for words presented only once (M = 0.72, 95% CI [.66, .79]), as shown in Figure 4.

The context effects were assessed using the ANOVA for context repetitions and word frequency of hit rates. The results showed a main effect of context repetition, $F(1, 23) = 5.06$, $p = .03$, $\eta^2_p = .18$, but not for frequency, $F(1, 23) = 0.10$, $p = .75$, $\eta^2_p = .004$, or interaction, $F(1, 23) = 1.53$, $p = .23$, $\eta^2_p = .06$. Pairwise comparisons showed that words repeated across context had a higher hit rate (M = 0.92, 95% CI [.88, .96]) than within-context repetitions (M = 0.89, 95% CI [.85, .93]). Figure 4 depicts this effect of the two repetition contexts on the hit rate, along with hit rate for single presentations for comparison.

Reaction times were lower for uncommon words but showed no effect for repetition or context. The repeated and nonrepeated groups, and word frequency ANOVA for hit rate reaction times, showed a main effect of repetition, $F(1, 23) = 6.89$, $p = .01$, $\eta^2_p = .23$, and frequency, $F(1, 23) = 14.40$, $p = .001$, $\eta^2_p = .38$, but no interaction effect, $F(1, 23) = 1.28$, $p = .26$, $\eta^2_p = .05$. The pairwise comparisons showed that repeated words (M = 418 ms, 95% CI [361, 475]) were recognized faster than nonrepeated words (M = 505 ms, 95% CI [411, 600]), and uncommon words (M = 409 ms, 95% CI [349, 469]) were recognized faster than common words (M = 514 ms, 95% CI [425, 603]) for both repeated and nonrepeated words.

FIGURE 3

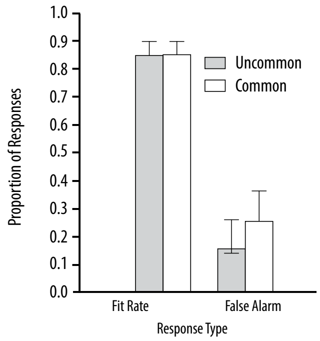

Figure 3. Comparison of hit rates and false alarm rates and common and uncommon words using a repeated-measures Analysis of Variance. Error bars show SEM.

The reaction times were further analyzed for context and word frequency effects. The ANOVA for hit rates showed a main effect of frequency, $F(1, 23) = 7.88$, $p = .01$, $\eta^2_p = .25$, but no main effects for context, $F(1, 23) = 2.80$, $p = .10$, $\eta^2_p = .10$, or interaction, $F(1, 23) = 0.03$, $p = .85$, $\eta^2_p < .001$. Uncommon words (M = 381 ms, 95% CI [327, 435]) were recognized faster than common words (M = 457 ms, 95% CI [384, 531]) in both across- and within-context repetition conditions.

Evaluating the Dual Process Model

In line with the dual process model, we predicted that participants should respond differently in the recognition task depending on if they saw the words multiple times within a single context or spread across the three contexts. To test this, we analyzed the proportion of remember judgments and calculated a corrected know proportion to reflect pure familiarity (Opitz, 2010). Corrected know responses were calculated by using the formula $K/(1-R)$ where K refers to proportion of know responses for hits and R refers to proportion of remember responses for hits. Corrected know response rate was calculated, as it assumes the independence paradigm by treating the two processes as being mutually exclusive (Yonelinas & Jacoby, 1995). Hit rates were used in this analysis because only old responses prompted the know or remember question to participants. The hits were divided into groups for across- and within-context repeated words, and word frequency. Remember response rates and corrected know response rates were calculated for all groups.

Across- and within-context repetitions did not affect remember and know judgments. We performed a three-way ANOVA for word frequency, context, and memory judgment type (corrected know vs. remember). There was no main effect for frequency, $F(1, 18) = 3.79$, $p = .16$, $\eta^2_p = .17$, context, $F(1, 18) = 1.52$, $p = .23$, $\eta^2_p = .78$, judgment type, $F(1, 18) = 5.04$, $p = .06$, $\eta^2_p = .22$, or context and judgment type interaction, $F(1, 18) = 0.00$, $p = .98$, $\eta^2_p < .001$. There was, however, a significant three-way interaction of memory judgment, word frequency, and context, $F(1, 18) = 5.04$, $p = .04$, $\eta^2_p = .22$. Hit rate was highest for know responses for uncommon words presented across contexts. Overall, the study context could not predict remember or know responses. Repeated presentations within the same context did not produce a higher proportion of remember responses, and across-context repetitions did not correspond to higher know responses.

Discussion

This project investigated the effects of stimulus repetition, context, and word frequency on recognition memory. We found that word frequency affected the speed and accuracy of recognition for both common and uncommon words. Contrary to our predictions, we found that uncommon words were recognized faster than common words, and common words were more likely to be false alarms. However, the effect size ($\eta^2_p = .38$) for this pattern was small and could indicate a possible random effect. It is also possible that the scale we used to select common and uncommon words (the Kučera and Francis frequency scale) did not produce lists of words that differed only in word frequency. More recent frequency scales use a larger corpus and include spoken language in determining the word frequency (Brysbaert & New, 2009).

The study revealed that repetition and context have prominent effects on recognition. Repeated words were recognized both faster and more accurately than non-repeated word. In addition, we found that repeating words across the three contexts resulted in better recognition for words, whereas recognition for words repeated within a single context was less accurate. However, the repeated words within a single context were still more accurate than single presentations. The descending order of accuracy from across-context to within-context, and lastly to nonrepeated words was consistent with Opitz (2010).

High accuracy for across-context presentations may indicate that participants were able to recognize words better when they saw the words in varying background colors and screen positions. This may speak to effects of extrinsic versus intrinsic context for recognition memory, mentioned by Godden and Baddeley (1980). They proposed that

FIGURE 4

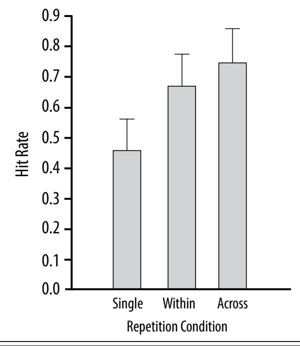

Figure 4. Hit rates for repeated words, within and across contexts, and nonrepeated words. Error bars show SEM.

extrinsic context such as features of the experiment room or perhaps the background color of the screen in the present study may not be as important for recognition as the intrinsic context of the words such as semantics.

Although the dual process model correctly predicted the effects of repetition, we did not find evidence to support its predictions about the effects of context on remember and know judgments, which other researchers were able to find with picture stimuli (Opitz, 2010). However, this may have been because of a repetition lag between repeated word presentations in our study. The repeated words within the same context were not repeated in continuous trials (that is, one after another), but rather there were several other words presented between the first, second, and third presentations of the same word. This lag in repetition might have produced weaker binding of the contextual features to the word. Future work examining recognition memory for words should consider the impact of the contextual congruence on memory performance. In the present study, the test conditions used a neutral context. In other words, the features of the test environment (word position and background color) were the same for all words, regardless of their context during learning. Future work could introduce congruent and incongruent test conditions. For example, if a word was presented on the left side then this aspect could be presented either in congruence (same side) or incongruence (opposite side) during the test recognition phase. Furthermore, context features and dual process of recognition and familiarity can be compared in different age groups to see if there is a decline in recognition abilities among young and old adults. Additionally, recognition processes can be examined using imaging and EEG to investigate the physiological bases for a single or dual process model.

Conclusion

We examined if word frequency, contextual features, and repetition affect recognition memory for words, along with examining the dual process model of recognition memory. The results showed significant main effects of repetition and frequency on recognition. The study, however, did not find any evidence to support the dual process model's prediction about independent processes of recognition and stimulus binding. Further experiments and models need to be explored to provide better clarity of the retrieval process of recognition memory.

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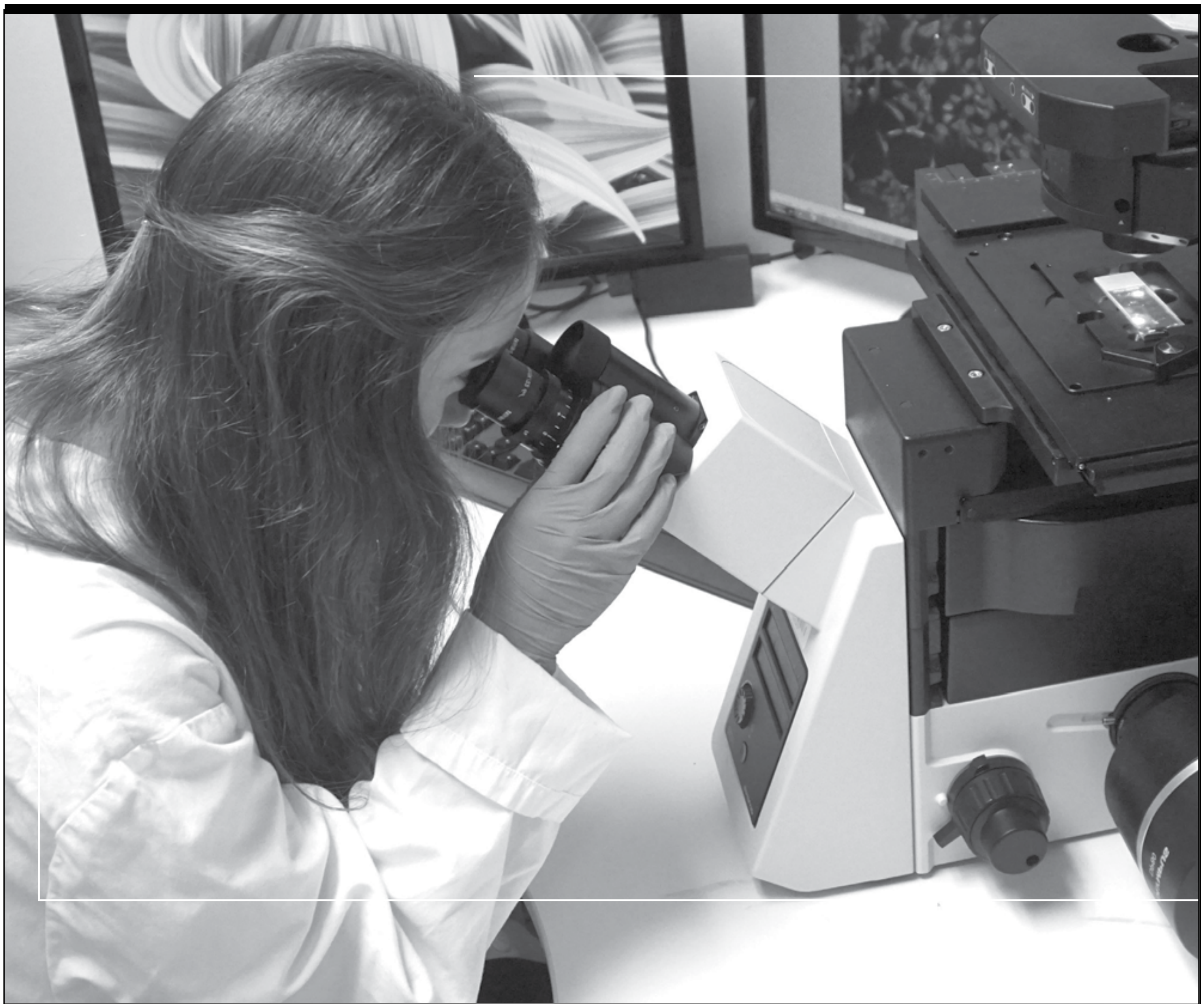

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