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Title:

Distinctiveness benefits novelty (and not familiarity), but only up to a limit: the prior knowledge perspective

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Abstract

Novelty is a pivotal player in cognition, and its contribution to superior memory performance is a widely accepted convention. On the other hand, mnemonic advantages for familiar information are also well documented. Here we examine the role of *experimental distinctiveness* as a potential explanation for these apparently conflicting findings. Across two experiments we demonstrate that conceptual novelty, an unfamiliar combination of familiar constituents, is sensitive to its experimental proportions: improved memory for novelty was observed when novel stimuli were relatively rare. Notably, no mnemonic advantage for conceptual novelty over familiarity was observed even when novel stimuli were extremely rare. Finally, memory levels for familiar items were similar across all experimental proportions, suggesting that encoding of familiar items is insensitive to distinctiveness manipulations. Together, these results imply that novelty does not always result in a mnemonic advantage. Instead, the effects of different aspects of novelty and familiarity should be explored orthogonally.

1 INTRODUCTION

2 Of all the traits associated with the beloved TV series character Kermit the Frog, it is
3 probably the green color which is most identifiable with him. This is his most memorable
4 feature, one of his most defining feats. So what happens when Kermit turns blue? Featuring
5 a novel blue-filtered version of Kermit, a recent clever ad by a Middle Eastern hospital alerted
6 parents to the importance of testing color blindness in children. Presumably, utilizing a
7 conceptually novel character – a blue twist of the old familiar green Kermit – ensured
8 heightened attention and a fortified mnemonic representation of the communicated
9 message. But is it indeed the case? Existing evidence presents conflicting conceptualizations
10 and results.

11 On the one hand, the capacity to prioritize novel stimuli over familiar ones is
12 considered a core aspect of human behavior. Preferential sensitivity to novelty allows
13 individuals to continuously adapt to an ever-changing environment by preferentially
14 attending and learning irregularities which may signal an upcoming danger (Alcaro &
15 Panksepp, 2011; Einstein, Mcdaniel, & Lackey, 1989; Friston, Penny, & Glaser, 2005; Kanai,
16 Komura, Shipp, & Friston, 2015; Schomaker & Meeter, 2015). Accordingly, novel stimuli have
17 been shown to enhance attention and to evoke reward related neural activity (Bunzeck &
18 Düz el, 2006; Düz el, Bunzeck, Guitart-Masip, & Düz el, 2010; Johnston, Hawley, Plewe, Elliott,
19 & DeWitt, 1990; Knight, 1996; Schomaker & Meeter, 2014; Wittmann, Daw, Seymour, &
20 Dolan, 2008). These benefits, in turn, have been shown to improve memory for novelty (Chun
21 & Turk-Browne, 2007; Kumaran & Duz el, 2008; Uncapher & Wagner, 2009; Wimmer &
22 Shohamy, 2012; Wittmann et al., 2005). Overall, the mnemonic benefit of novelty is a widely
23 accepted convention among memory researchers, particularly in the field of neuroscience

(e.g., Axmacher et al., 2010; Friston, 2010; Geraci, Mcdaniel, Miller, & Hughes, 2013; Kinsbourne & George, 1974; Kishiyama & Yonelinas, 2003; Kumaran & Maguire, 2009; Snyder, Blank, & Marsolek, 2008; Stoppel et al., 2009; Tulving & Kroll, 1995).

In a seemingly direct contradiction, a large body of work demonstrates a mnemonic advantage for repetitive familiar items (e.g., Badham & Maylor, 2015; Bein et al., 2015; Craik & Tulving, 1975; Ebbinghaus, 1885/1913; Maril et al., 2011; Poppenk, Köhler, & Moscovitch, 2010; Schulman, 1974). One prominent example is the ‘semantic congruency effect’ (SCE), whereby stimuli that are congruent with previous knowledge are better remembered than novel stimuli that are incongruent with pre-existing semantic representations (Bein et al., 2015; Brewer & Treyens, 1981; Craik & Tulving, 1975; Gronau & Shachar, 2015; Schulman, 1974; Tibon, Gronau, Scheuplein, Mecklinger, & Levy, 2014; van Kesteren, Rijpkema, Ruiter, & Fernández, 2013). Case in point, the elements of the schema-congruent stimulus “yellow banana” are associated with better retrieval rates in subsequent recall and recognition tests than the elements of the schema-incongruent stimulus “purple banana” (Bein et al., 2015; Schulman, 1974). Notably, schema-incongruent pairs constitute conceptual novelty, unfamiliar combinations of familiar words or variations of conceptually familiar schematic prototypes (Kagan, 2009; Wisniewski, 1997). Thus, while novelty paradigms suggest a preferred mnemonic status for novel events, SCE and additional findings (Badham & Maylor, 2015; Kole & Healy, 2007; Poppenk et al., 2010) indicate that familiarity elicits improved memory.

Two major differences characterize these two conflicting research traditions. First, novelty-supporting evidence were garnered mainly when novelty was defined within a specific experimental context (e.g., words which were not familiarized in the particular

experiment but were nonetheless pre-experimentally familiar (Tulving & Kroll, 1995); words with lower frequency compared to other words in the experimental list (Glanzer & Adams, 1985)). Familiarity mnemonic enhancement, on the other hand, was demonstrated also when compared to conceptually novel stimuli which possess no pre-existing representation (e.g., an unknown proverb; (Poppenk et al., 2010)).

Second, the degree of distinctiveness associated with novel stimuli differs between these traditions (for an elaborate discussion of the mechanisms supporting the distinctiveness account, see Hunt & Lamb, 2001; Hunt, 1995). In paradigms demonstrating the novelty mnemonic advantage, novel stimuli are considered distinct compared to their familiar counterparts. This distinction can be observed in experimental novelty paradigms, whereby novel stimuli are associated only with a unique encoding context whereas familiar stimuli are presented in multiple contexts (Dobbins, Kroll, Yonelinas, & Liu, 1998; Kormi-Nouri, Nilsson, & Ohta, 2005; Tulving & Kroll, 1995). In isolation paradigms, the novel item is categorically distinct from its surrounding items (Hunt & Lamb, 2001; Hunt, 1995; Kishiyama & Yonelinas, 2003; Knight, 1996; Michelon, Snyder, Buckner, McAvoy, & Zacks, 2003; von Restorff, 1933, as cited in Hunt, 1995). Similar mechanisms have been suggested to account for additional novelty-related findings such as the low frequency words advantage in recognition memory (Glanzer & Adams, 1985; Reder, Paynter, Diana, Ngiam, & Dickison, 2007) or the mnemonic advantage sometimes found for bizarre pictures or sentences (e.g., The MAID licked AMMONIA off the TABLE) in free recall (Hirshman, Whelley, & Palu, 1989; McDaniel & Bugg, 2008; McDaniel, Einstein, DeLoach, May, & Brady, 1995).

Supporting the role of distinctiveness for novelty-enhanced memory, novelty effects dissipated when these sources of distinctiveness were eliminated, either by equating

experimental contexts for familiar and novel stimuli (while keeping their relative novelty at encoding) (Dobbins et al., 1998; McDaniel, Dornburg, & Guynn, 2005; Poppenk et al., 2010) or by forcing unique processing for each stimulus (Hunt & Lamb, 2001; Hunt, 1995). Importantly, familiarity mnemonic advantage was demonstrated mainly in paradigms which included equal experimental contexts for familiar and novel stimuli (Craig & Tulving, 1975; Maril et al., 2011; Schulman, 1974; Staresina, Gray, & Davachi, 2009), possibly preventing any distinctiveness-related advantage for novel stimuli.

Given these two sources of difference, it remains unclear whether different classes of novelty (experimental versus conceptual) result in different mnemonic effects, or, alternatively, it is the orthogonal factor of distinctiveness which drove the disparate findings. If distinctiveness is indeed the major force driving the enhanced memory observed for novel events, allowing it to come into play in paradigms typically demonstrating familiarity-advantage such as the SCE paradigm should dramatically alter their effect. This is the focus of the current investigation.

In the following experiments we utilized conceptually familiar and novel stimuli in a standard SCE paradigm and manipulated the relative distinctiveness of each class of stimuli between participants. Familiarity and novelty were operationalized by noun-adjective word pairs which either had or did not have a pre-experimental association, respectively. Distinctiveness was parametrically modulated via the proportion of the familiar and novel stimuli in the experimental list (Icht, Mama, & Algom, 2014; see also list-wise proportion manipulation in attention and semantic priming; Blais, Harris, Sinanian, & Bunge, 2015; Bugg & Crump, 2012; Tweedy, Lapinski, & Schvaneveldt, 1977). A subsequent surprise noun recognition test was utilized to examine memory effects for items encoded in a familiar or in

a novel context. Importantly, as the only difference between the nouns was their encoding context (accompanying adjective), omitting it at test controlled for possible discrimination demands for both conditions (for possible effects of differing discrimination demands, see Dobbins et al., 1998; Poppenk et al., 2010; Reder et al., 2007).

If novelty-enhanced memory is indeed dependent upon distinctiveness, memory rates for items encoded in a conceptually novel context should improve as their experimental proportion decrease. Moreover, memory for novel events should exceed that of familiar events when the former are presented at extremely low proportions and hence are extremely distinct (similarly to the isolation/distinctiveness effect; Hunt, 1995; Kishiyama & Yonelinas, 2003). These predictions were explored in Experiment 1. Interestingly, distinctiveness manifested as low experimental proportions should boost mnemonic performance regardless of content. Thus, rendering the conceptually familiar events more distinct is predicted to boost their memorability as well. Therefore, in addition to replication and extension with a larger set of stimuli, Experiment 2 served to test the contribution of experimental proportions to encoding of familiarity/novelty for all experimental proportion levels. This was achieved by fully crossing familiarity/novelty with experimental proportions. In summary, across two experiments we tested three hypotheses-driven questions: (1) whether distinctiveness (manifested as an experimental proportion manipulation) affects mnemonic performance for novel items, and moreover (2) whether our manipulation could achieve a mnemonic advantage for novelty, at least in the extreme proportions condition, where distinctiveness is maximal; finally, (3) we tested whether the same manipulation affects mnemonic performance for familiar items.

EXPERIMENT 1

METHODS

Participants

The experiment included 96 undergraduate students from the Hebrew University of Jerusalem (66 females; mean age: 24.23, range: 20-33). Data from two participants were corrupted due to a technical malfunction; two additional participants were recruited in their stead. The number of participants was determined by a-priori power calculations, conducted in GPower 3.1.3 (Faul, Erdfelder, Lang, & Buchner, 2007), which indicated that 88 participants (22 per group) are required to obtain power of 0.95 for an interaction between group and familiar/novel conceptual status (see procedure) with partial η^2 of 0.05. Two additional participants were recruited per group to allow outlier exclusion where necessary. Six participants from different experimental groups were excluded due to extreme values (more than three standard deviations from the group's mean): extreme false alarm rates for three participants, extreme reaction time for two participants and poor performance at the incidental encoding task for one participant. Altogether, analyses included data gathered from 90 participants (similarly divided between groups; range 21-24 participants per group).

All participants were self-reportedly native Hebrew speakers with normal or corrected-to-normal vision. Participants received either payment of 15 NIS (equivalent to 4\$) or class credit for participation, and they all provided a written informed consent in a manner approved by the Faculty of Social Science Ethics Committee, The Hebrew University of Jerusalem.

Stimuli

A total of 80 Hebrew nouns ('items') were paired with congruent adjectives ('context') to form familiar target pairs. Another set of 80 pairs was constructed by re-pairing the same items and contexts in novel combinations [i.e., each adjective that appeared in a familiar pair with one noun (e.g., "yellow BANANA") was also used to construct a novel pair with another noun (e.g., "yellow ZEBRA")]. The items were divided into two lists of 40 items each, one list to be used for familiar pairs and another for novel pairs, counter-balanced between participants. Each participant saw 40 pairs (see Procedure), with the remaining 40 items designated as foils for the subsequent recognition test. Each word (noun or adjective) appeared only once, either in a familiar pair or in a novel pair. Allocation of nouns and adjectives to the different experimental conditions (familiarity/novelty and experimental proportion) was completely counter-balanced between participants.

These stimuli were selected from a larger list of 360 pairs that were used in previous experiments (Bein et al., 2015), based on the consistency of congruency ratings in pilot studies (for details, see Reggev, Bein, & Maril, 2016). The nouns and adjectives were 2-7 letters long (mean nouns: 3.96 letters, mean adjectives: 4.84 letters). Care was taken to ensure that word length and single-word frequency assessed by previously established norms did not significantly differ between the two experimental lists (Frost & Plaut, 2005). To avoid primacy and recency effects, six additional pairs (three familiar) were chosen as fillers and presented at the onset and offset of the incidental encoding session. These pairs were not counter-balanced and were not included in any of the analyses.

Procedure

The experiment consisted of three main phases: incidental encoding, distraction task and retrieval (see overall task design in Fig. 1). Participants were tested individually, each

receiving detailed instructions and a short practice session before each phase. Prior to entering the room, participants were randomly assigned to one of four between-subject experimental conditions which differed in the relative proportion of novel pairs (out of a total of 40 pairs): either 50% (20 pairs), 12.5% (five pairs), 7.5% (three pairs) or 2.5% (one pair). The rest of the incidentally encoded pairs were familiar.

In the incidental encoding phase, participants were asked to decide whether the context (adjective) can describe the item (e.g., "can a BANANA be yellow?"), and to indicate their "yes/no" response by pressing one of two possible keyboard keys. This task was chosen for compatibility with previous SCE studies (Bein et al., 2015; Schulman, 1974). Notably, novel stimuli (e.g., "purple BANANA") required a different response than familiar stimuli, further stressing their distinctiveness. Each pair was presented on the screen for 2.5-s, followed by a 0.5-s fixation cross. Participants could respond during the presentation of the stimuli or the fixation. Both the item and the context appeared simultaneously in the center of the screen, written in white on a black background. The pairs appeared in random order.

Following the encoding phase, participants were engaged in a visual block-counting task for 3.5 minutes, to prevent a ceiling effect in memory performance. The last phase of the experiment consisted of a surprise noun recognition memory test. The item words (nouns) appeared alone in the middle of the screen (40 nouns from the encoding phase alongside 40 foils). Crucially, targets and foils were indiscernible in terms of novelty and familiarity, as the conceptual familiarity/novelty manipulation hinged entirely upon the association between items and their contexts, with the latter appearing only at encoding. This design precluded the calculation of separate false alarm rates for familiar and novel stimuli. Consequently, false alarm rates represent a general bias to endorse context-free non-encoded nouns as old items.

The words were presented on the screen, one at a time, for 2.25-s followed by a 0.75-s of fixation. Participants were asked to indicate whether the target word was (or was not) presented in the first phase, by pressing one of two possible keys on a keyboard. The items were presented in random order. At the end of the experiment participants were debriefed and asked whether they had suspected a later memory test.

Analysis

Mixed effect analysis was chosen as the principal analysis as it allows to fit models to unbalanced data sets (e.g., the difference between familiar and novel in the 2.5% condition), and provides modestly enhanced power for small numbers of observations (Baayen, Davidson, & Bates, 2008). Furthermore, only mixed effects models simultaneously take into account possible participant and item effects which might inflate Type I or Type II errors (Baayen et al., 2008; Judd, Westfall, & Kenny, 2012). Analyses of variance (ANOVAs) were conducted for verification where appropriate and provided similar results; these analyses are available upon request.

Linear Mixed Models (LMM) were implemented using the lmer and glmer functions of the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) for R (R. Core Team, 2014). Classification accuracy at encoding and memory performance were analyzed using a logit Generalized Linear Mixed Models (gLMM), as these models preclude spurious effects and have more power than standard ANOVAs for categorical dependent variables (Jaeger, 2008). For all analyses we entered conceptual status (familiar/novel), experimental proportions and their interaction into the models as fixed effects. Conceptual status was coded using an unweighted dummy variable with familiar pairs as the reference group, because we were specifically interested in the effects of familiarity and novelty as a result of the different

proportions of stimuli in the different groups. The between-participants experimental proportion was sum-coded and weighted according to the group size with the equal proportions group defined as the reference. As random effects, unless otherwise noted, we included intercepts for participants and items, as well as by-participant and by-item random slopes for the effect of conceptual status.

RESULTS AND DISCUSSION

Incidental encoding performance. A logit gLMM regression was conducted to test whether correctly classifying the conceptual status of a given pair (familiar versus novel) at encoding differed as a function of any of the experimental factors. This model included a random intercept for participants and a by-participant slope for conceptual status¹. Analysis results revealed that neither conceptual status nor experimental proportion had an effect on classification accuracy (conceptual status: $\beta \pm S.E. = 0.3 \pm 0.4$, $z = 0.76$)², confirmed by leave-one-out model comparison for conceptual status ($\chi^2 = 0.65$, $df = 1$, $p > 0.4$) and experimental proportion group ($\chi^2 = 3.15$, $df = 3$, $p > 0.3$), indicating that classification accuracy did not differ between experimental conditions (see Table 1 for descriptive statistics). Given the high classification accuracy ($\beta \pm S.E. = 3.35 \pm 0.14$, indicating a probability of 96.62% for correctly classifying a word pair as familiar or novel), and for compatibility with previous experiments (Craik & Tulving, 1975; Maril et al., 2011; Staresina et al., 2009), subjective classification

¹ Including a random intercept for item in this analysis led to a failure of the model to converge; therefore, no random effects for items were included.

² Categorical predictors with more than two levels are represented by several encoding vectors in a regression analysis, and estimated separately for each vector; in the current case, group effects were estimated separately for each of the 3 predictors comprising the group factor, all p values > 0.15 .

ratings were used here and in Experiment 2 as the independent factor defining conceptual status of familiarity versus novelty³.

Recognition memory performance. As memory performance was well above chance⁴, we continued to test our critical hypothesis, namely, that the effect of novelty on recognition memory will differ as a function of experimental proportions. To that end, we conducted a logit gLMM regression with conceptual familiar-versus-novel status, experimental proportion and their interaction as the predictors, and recognition success of previously encoded items as the dependent variable (see Table 2 for descriptive statistics). The leave-one-out model comparison procedure revealed a significant effect of conceptual familiar-versus-novel status on recognition memory scores, ($\chi^2=19.04$, $df = 1$, $p < 0.001$), indicating that, overall, novel items were 10% less likely to be recognized (novel items: $\beta \pm S.E. = -0.63 \pm 0.16$, $z = -3.86$, $p < 0.001$; intercept: $\beta \pm S.E. = 1.72 \pm 0.15$, $z = 11.54$). Experimental proportion had no effect on recognition memory scores ($\chi^2=6.1$, $df = 3$, $p > 0.1$). However, the interaction between conceptual status and experimental proportion was significant ($\chi^2=8.64$, $df = 3$, $p < 0.05$), confirming our hypothesis that experimental proportion influences the familiarity/novelty effect (see Fig. 2).

To understand the cause of the interaction, we analyzed the effects of conceptual familiar-versus-novel status separately at each level of experimental proportion (i.e., simple slopes). This analysis indicated that while *novel* items were 17% less likely to be recognized in

³ Conducting all reported analyses with correct responses to the a-priori stimuli classification provided qualitatively identical effects to the analyses reported in the main text; additionally, conducting the subjective analysis after removing five participants whose classification accuracy differed by more than 2 standard deviations from the grand average led to similar effects as well.

⁴ Encoded items received significantly more “old” responses than foils, as indicated by a contrast of old items (familiar and novel) versus foils coded in a logit gLMM applied to all recognition trials ($\beta \pm S.E. = 2.44 \pm 0.1$, $z = 23.88$, $p < 0.001$). Notably, as the test included nouns alone, no discrimination between novel and familiar items could have been performed. Therefore, foils are treated equally for both familiarity and novelty.

the equal proportions group ($\beta \pm S.E. = -0.97 \pm 0.23$, $z = -4.23$, $p < 0.001$; intercept: $\beta \pm S.E. = 1.72 \pm 0.23$, $z = 7.36$), they were recognized as well as *familiar* items in the low proportions groups ($\beta \pm S.E. = -0.39 \pm 0.44$; -0.53 ± 0.39 ; 0.24 ± 0.65 , for the 2.5%, 7.5% and 12.5% groups, respectively; all Z values < 1.38 and all p-values > 0.1). This result suggests that, as predicted, participants remember novel noun-adjective pairs better when the novel events were a minority in the encoded items⁵. But while distinctiveness facilitated encoding, it did not produce a novelty memory advantage over familiarity even when only one single novel event occurred in the experimental session. Furthermore, only the encoding of novel items seemed to have been affected by the experimental proportion manipulation. Re-analyzing the interaction by separately examining the effects of experimental proportions for each level of conceptual status supported this conclusion. While experimental proportion indeed contributed to the variance explained by the model for novel items ($\chi^2 = 10.64$, $df = 3$, $p < 0.05$), it had no significant effect for familiar items ($\chi^2 = 2.28$, $df = 3$, $p > 0.5$).

Reaction time. Reaction time data for the incidental encoding task were log transformed⁶ and analyzed in a LMM with conceptual familiar-versus-novel status, experimental proportion group and their interaction as the predictors. The leave-one-out model comparison procedure exposed a significant effect of conceptual status ($\chi^2 = 56.72$, $df = 1$, $p < 0.001$), experimental proportion group ($\chi^2 = 9.96$, $df = 3$, $p < 0.05$) and their interaction ($\chi^2 = 10.35$, $df = 3$, $p < 0.05$; see Table 3 and Fig. 3). Simple slopes analysis using non-transformed data indicated that the effect of conceptual status on reaction time was

⁵ Note that the recognition memory test included nouns alone, therefore eluding any experiment-induced discrimination between nouns that were previously accompanied by familiar or novel context. The obtained differences thus resulted either from improved encoding or enhanced participant-induced retrieval processes.

⁶ An identical analysis performed on non-transformed response latencies yielded qualitatively equivalent results.

significant for all experimental proportion groups ($\beta \pm S.E = 272.4 \pm 58.45, 259.29 \pm 46.8, 200.48 \pm 42.14, 116.27 \pm 35.53$ for the 2.5%, 7.5%, 12.5% and 50% groups, respectively; all t -values $> 3.27^7$). Post-hoc analysis, implemented as orthogonal contrasts coded in the LMM, showed that reaction time difference between familiar and novel pairs in the equal proportion group was significantly reduced compared to other groups ($\beta \pm S.E. = -93.06 \pm 31.29, t = -2.97$); no additional comparisons demonstrated significant differences. Re-analyzing the interaction by separately examining the effects of experimental proportion on reaction time for each level of conceptual status revealed that while experimental proportions indeed contributed to the variance explained by the model for novel items ($\chi^2=12.7, df = 3, p < 0.01$), it had no significant effect for familiar items ($\chi^2=7.48, df = 3, p > 0.05$).

To summarize the results from Experiment 1, the original hypothesis of increasing mnemonic performance for novelty as its experimental proportion decreases was largely confirmed. Recognition memory for novel items was better when their experimental proportion was low (one-eighth of all experimental trials or less) compared to the same items in an equal proportion context. However, we did not find any evidence of a mnemonic advantage for novelty over familiarity: at equal proportion, novelty demonstrated a mnemonic disadvantage, whereas at a rare LOW experimental proportion (a single event in a list of 40 pairs) mnemonic performance for novelty was similar to that of familiarity, hinting that not all types of novelty necessarily guarantee improved performance in and of themselves. Interestingly, recognition rates for items encoded in familiar contexts were stable

⁷ The significance of simple effects could not be tested using model comparison, as was done for the main effects and interaction. However, this t -value would be significant at the .05 level for as little as 3 degrees of freedom.

across experimental proportions in spite of the fact that different people participated in each proportion condition, suggesting that novel contexts are especially sensitive to the composition of the experimental list. Reaction time effects were qualitatively similar, with encoding performance for novel pairs slower for low experimental proportions, while reaction times for familiar pairs remained steady across experimental proportions.

EXPERIMENT 2

The results of Experiment 1 hinted that distinctiveness does indeed play an important role in the processing of to-be-remembered events – but exclusively for novel events. No effect of distinctiveness on the encoding of familiar events was evident. However, Experiment 1 focused specifically on cases in which the experimentally infrequent events were novel. It could be the case that low experimental proportion boosts mnemonic performance as a general phenomenon; indeed, the isolation effect demonstrates that infrequent/distinct items are better remembered when they are sufficiently distinct in comparison to frequent stimuli (Hunt & Lamb, 2001; Hunt, 1995; von Restorff, 1933). Moreover, experimental infrequency has been recently shown to be associated with similar neural correlates across different tasks, suggesting that infrequent events elicit a ubiquitous neural response which is insensitive to the specifics of the processed content (Wijeakumar et al., 2015). Consequently, infrequent experimental events, whether novel or familiar, could be better remembered relative to frequent experimental events regardless of their content. Such a result would conceptually replicate the isolation effect (Hunt, 1995) and demonstrate that the role of distinctiveness by experimental proportions is not limited to novel events.

To formally test this possibility, and to replicate the results from Experiment 1 with increased power in a more common experimental setting, Experiment 2 included five

between-participant experimental proportion conditions which varied in the relative proportion of novel pairs: either 5%, 22%, 50%, 78% or 95%. The latter two groups included a majority of novel word pairs, thus rendering familiarity as the experimentally distinct condition. To provide more power and experimental compatibility with modern novelty studies each participant in Experiment 2 incidentally encoded 180 stimuli, divided between familiar and novel pairs according to the between-participant experimental proportion condition (Bein et al., 2015; Krebs, Boehler, De Belder, & Egner, 2015). If low experimental proportions boost mnemonic performance regardless of the content of the distinct stimuli, recognition scores in Experiment 2 should demonstrate a full cross-over interaction between familiar-versus-novel conceptual status and experimental proportions: memory rates for different events will be highest when infrequent and will decrease as their proportions increase regardless of novelty or familiarity. Alternatively, if experimental proportions exclusively affect novel events, memory rates for familiar events (and possibly their reaction time) should be stable across proportions.

METHODS

Participants

Experiment 2 included 101 undergraduate students from the Hebrew University of Jerusalem (50 females; mean age: 24.65, range 19-31). A-priori power calculations, conducted in GPower 3.1.3 (Faul et al., 2007), determined that 95 participants (19 per group) are required to obtain power of 0.95 for an interaction between group and congruency with partial η^2 of 0.05 (see procedure). One or two additional participants were recruited per group to allow outlier exclusion where necessary. Three participants were excluded due to extreme values of more than three standard deviations from the group's mean: two participants had

extreme false alarm rates and one participant provided extreme reaction time data. Two additional participants were excluded after completing the experiment because they were exposed to the same stimuli when they participated in a different experiment. Altogether, analyses included data collected from 96 participants (similarly divided between groups; range 18-20 participants per group).

All participants were self-reportedly native Hebrew speakers with normal or corrected-to-normal vision. Participants received either payment of 20 NIS (equivalent to 5\$) or class credit for participation, and provided a written informed consent in a manner approved by the Faculty of Social Science Ethics Committee, The Hebrew University of Jerusalem.

Materials

Stimuli were constructed identically to Experiment 1. For Experiment 2 we utilized all 360 pairs from a previous experiment (see Bein et al., 2015, experiment 1 for details), with half of them included in the incidental encoding phase, counter-balanced between participants.

Procedure and Analyses

Procedure and analysis approach were identical to those in Experiment 1 with the exception of a few modifications in procedure. First, Experiment 2 included five experimental groups varying in experimental proportions of novel (or familiar) events: either 5% (9 out of 180 pairs), 22% (40 pairs), 50%⁸, 78% or 95%. The stimuli appeared in the incidental encoding

⁸ To allow full counter-balancing between all experimental conditions (conceptual status - familiar versus novel - and encoded versus foil items), only 89 pairs of each conceptual status were included in the 50% group.

phases in random order with a restriction that experimentally infrequent stimuli will be distributed roughly uniformly across the entire encoding phase. For the equal proportion group, no more than four consecutive trials of each conceptual status were allowed. The recognition phase included all 360 items which were presented in random order with no more than four old (or foil) consecutive trials allowed.

RESULTS AND DISCUSSION

Incidental encoding performance. A logit gLMM regression revealed that the effect of experimental proportion on classification accuracy approached significance, as estimated by the leave-one-out model comparison ($\chi^2=8.59$, $df=3$, $p=0.07$). Examining the separate coding variables for experimental proportion showed that classification performance for the 22% novel items group was marginally better than the grand average classification accuracy ($\beta \pm S.E. = 0.42 \pm 0.22$, $z = 1.92$, $p = 0.055$). Importantly, neither conceptual status ($\beta \pm S.E. = 0.06 \pm 0.23$, $p > 0.7$) nor its interaction with experimental proportion group had an effect on classification accuracy. This was confirmed by leave-one-out model comparisons for conceptual status ($\chi^2=0.03$, $df=1$, $p > 0.8$) and its interaction with experimental proportion group ($\chi^2=3.04$, $df=4$, $p > 0.5$), indicating that classification accuracy did not differ between familiar and novel pairs (see Table 1 for descriptive statistics).

Recognition memory performance. Similarly to Experiment 1, memory performance was well above chance⁹. The effect of experimental proportion on memory performance for novelty was tested through a logit gLMM regression with conceptual status, experimental proportion and their interaction as the predictors; recognition success of previously encoded

⁹ Encoded items received significantly more “old” responses than foils, as indicated by a contrast of old items (familiar and novel) versus foils coded in a logit gLMM applied to all recognition trials ($\beta \pm S.E. = 2.17 \pm 0.08$, $z = 26.91$, $p < 0.001$).

items was the dependent variable. Like in Experiment 1, the leave-one-out model comparison procedure resulted in a significant effect of conceptual status on recognition memory scores, ($\chi^2=29.04$, $df = 1$, $p < 0.001$): Novel items were 8.5% less likely to be recognized (novel items: $\beta \pm S.E. = -0.37 \pm 0.07$, $z = -5.58$, $p < 0.001$; intercept: $\beta \pm S.E. = 0.81 \pm 0.09$, $z = 9.39$). Experimental proportions had no effect on recognition memory scores ($\chi^2=6.6$, $df = 4$, $p > 0.1$). Importantly, we found a significant interaction between conceptual status and experimental proportion ($\chi^2=22.62$, $df = 4$, $p < 0.001$). As hypothesized, and like in Experiment 1, experimental proportion had an effect on the familiarity/novelty effect (see Table 2 and Fig. 4).

Our next objective was to examine the main hypothesis of Experiment 2 and to critically test whether the effects of experimental proportions are limited to novel events or generalized to familiar events. We analyzed the effects of experimental proportion separately at each level of conceptual status (i.e., simple slopes). A visual inspection of Fig. 4 clearly reflects that the effects of experimental proportion were indeed limited to novel events; recognition memory performance for items encoded in a familiar context was similar across all experimental proportion groups. Formally testing these trends illustrated that while experimental proportion did in fact contribute to the variance explained by the model for novel items ($\chi^2=19.52$, $df = 4$, $p < 0.001$), it had no significant effect for familiar items ($\chi^2=1.38$, $df = 4$, $p > 0.8$). A test of linear and quadratic basis functions (coded as predictors in the separate models) indicated that recognition performance for items encoded in a novel context improved linearly as experimental proportions decreased ($\beta = 0.75$, $SE = 0.18$, $z = 4.12$, $p < 0.001$); no evidence were obtained for a quadratic trend for novel events, nor for any polynomial trends in recognition memory of familiar events (all Z values < 0.7 , all p values $>$

0.5). Finally, and once again like Experiment 1, re-analyzing the interaction by separately examining the effects of conceptual status for each level of experimental proportion confirmed that novel items were recognized as well as - but not better than - familiar items in the low proportion groups ($\beta \pm S.E. = 0.16 \pm 0.15$, $z = 1.1$; $\beta \pm S.E. = -0.16 \pm 0.14$, $z = -1.14$ for the 5%, and 22% groups, respectively; all p -values > 0.2). Additionally, novel items were less likely to be recognized in the equal proportion group or in the frequent novelty groups ($\beta \pm S.E. = -0.49 \pm 0.12$; $\beta \pm S.E. = -0.69 \pm 0.16$; $\beta \pm S.E. = -0.63 \pm 0.16$ for the 50%, 78% and 95% groups, respectively; all p -values < 0.001).

Reaction time. Reaction time data for the incidental encoding task were log transformed¹⁰ and analyzed in a LMM with conceptual status, experimental proportion group and their interaction as the predictors. The leave-one-out model comparison procedure revealed a significant effect of conceptual status ($\chi^2=18.23$, $df = 1$, $p < 0.001$), experimental proportion group ($\chi^2=9.62$, $df = 4$, $p < 0.05$) and their interaction ($\chi^2=100.88$, $df = 4$, $p < 0.001$; see Table 3). Simple slopes analysis using non-transformed data indicated that novel events received slower responses, compared to familiar events, when in low or equal proportions ($\beta \pm S.E. = 336.05 \pm 29.72$, 190.86 ± 28.64 , 146.33 ± 26.97 , for the 5%, 22%, and 50% groups, respectively; all t -values > 5.43). However, when novel events were the dominant event type in the experiment they evoked response latencies comparable (78% novel events: $\beta \pm S.E. = 5.14 \pm 28.1$, $t < 1$) or even faster (95% novel events: $\beta \pm S.E. = -198.5 \pm 31.46$, $t = 6.31$) than the response latencies for familiar events. Correspondingly, reaction time for both familiar and novel events followed a significant linear trend, as indicated by dedicated predictors coded in the LMM ($\beta \pm S.E. = -169.14 \pm 47.99$, $t = -3.52$ for familiar events, $\beta \pm S.E. = 258.02 \pm 51.34$, $t =$

¹⁰ An identical analysis performed on non-transformed response latencies yielded qualitatively equivalent results.

5.03). While the linear trend for novel events resulted from monotonically slower responses as novelty became more distinct (see Fig. 3), the linear trend for familiar events seemed to have resulted from a deviation of one experimental proportion group from the overall mean response time. Post-hoc analysis, implemented as orthogonal contrasts coded in the LMM, showed that reaction time for familiar items was significantly slower for the 95% novel items group compared to all other groups ($\beta \pm S.E. = 222.84 \pm 44.32$, $t = 5.03$), with no other significant between-groups differences in reaction time for familiar events (all t -values < 1.29).

In summary, Experiment 2 replicated and extended the results of Experiment 1. Mnemonic preference for novelty increased as its experimental proportion decreased: Items encoded in a novel context when their experimental proportion was low (22% or 5%) were remembered better than the same items in a more experimentally common context. Once again, no evidence for mnemonic advantage for novelty over familiarity was found, even when novel events were experimentally rare, suggesting that novel events do not lead to unique memory performance in and of themselves. Moreover, items encoded in familiar contexts demonstrated stable recognition memory across experimental proportions, even when familiarity was experimentally distinct, demonstrating that only conceptually novel events benefit from distinctiveness.

GENERAL DISCUSSION

The objective of our study was to better characterize the contribution of distinctiveness to previous contradicting findings attributing mnemonic advantage to novelty and familiarity (Axmacher et al., 2010; Badham & Maylor, 2015; Bein et al., 2015; Gronau & Shachar, 2015; Hirshman et al., 1989; Kishiyama & Yonelinas, 2003; Meeter, Murre, &

Talamini, 2004; Michelon et al., 2003; Schulman, 1974; Stoppel et al., 2009; Tulving & Kroll, 1995; van Kesteren et al., 2013). Across two experiments we found that an experimental distinctiveness manipulation – varying experimental proportions – differentially affected items encoded in a conceptually novel (incongruent) or familiar (congruent) context: Distinctiveness was monotonically correlated with memory performance and reaction time (RT) for items encoded in a novel context, whereas memory and RT performance for familiar items was overall stable across all proportion conditions. However, subsequent memory for distinct novel events never exceeded that of familiar events, indicating that novelty does not always lead to a mnemonic advantage. Below we discuss possible interpretations of these effects and relate them to previous research.

The Unique Benefit of Novelty?

According to our findings, the mnemonic benefit of novelty is not as ubiquitous as previously thought (Biederman & Vessel, 2006; Kishiyama & Yonelinas, 2003; Schomaker & Meeter, 2015; Tulving & Kroll, 1995). The mnemonic improvement for novel items with decreasing experimental proportions was apparently capped by the mnemonic performance for familiar items (for a similar conclusion, see Poppenk et al., 2010). Even when novel events in this investigation were experimentally rare their mnemonic performance did not exceed that of familiar events.

Notably, when novel stimuli appeared in low experimental proportions they resulted in a strong violation of the expectations formed by experimental history, similar to classic experimental novelty or distinctiveness studies (Hunt & Lamb, 2001; Hunt, 1995; Kishiyama & Yonelinas, 2003; Schomaker & Meeter, 2015; Tulving & Kroll, 1995). Thus, it seems unlikely that distinctiveness or this type of expectation violation can lead, in and of themselves, to

mnemonic benefits over expectation-matching events. Therefore, our findings suggest that when the novelty of stimuli is defined based on one's life-experience, rather than on a specific experimental context, it may not confer a mnemonic advantage.

An additional contribution that emerges from our data is a possible boundary condition for recent demonstrations of enhanced memory for incongruent attention-attracting stimuli (Krebs et al., 2015; Rosner, D'Angelo, MacLellan, & Milliken, 2015). In these studies, recognition memory for conflict-inducing incongruent stimuli (e.g., a male face on which the incongruent label "FEMALE") was better than recognition memory for congruent or neutral stimuli. Our novel knowledge-incongruent stimuli also evoked a conflict with pre-existing knowledge that was clearly reflected in their higher response latencies. However, we did not observe the mnemonic improvement found in the studies referenced above, implying that not all sources of conflict necessarily result in improved memory. Overall, we propose that claims about novelty and incongruency be made with consideration of the multiple aspects comprising novelty (see also Kagan, 2009).

The Effect of Experimental Proportions on Novel events

Items encoded in a novel context displayed monotonically increasing memory as their experimental proportion at encoding decreased, in line with the classic distinctiveness account (e.g., Hunt, 1995; Worthen & Marshall, 1996). However, the same account would predict that infrequent/distinct items should be better remembered than the frequent/indistinct items on the same experimental list. This was not the case in our experiment. When novelty was experimentally infrequent (and familiarity experimentally frequent), the memory rates for familiar and novel stimuli were comparable. Importantly, each stimulus in our design was a unique noun-adjective pair and had to be considered

separately from other stimuli. Thus, each event benefited from distinctive processing, possibly constraining the emergence of group distinctiveness advantage for experimentally infrequent events (Hunt & Lamb, 2001).

Interestingly, several recent investigations of additional mechanisms resonate with the current findings. For instance, the attention and control literatures have extensively employed experimental proportion manipulations (Bugg and Crump, 2012; Logan and Zbrodoff, 1979; Logan et al., 1984; see also Tweedy et al., 1977 and Hutchison, 2007 for conceptually similar effect in semantic priming). In a typical experimental list, response-incongruent words (e.g., the word “GREEN” presented in red in a Stroop task) can appear either frequently (80% of trials), infrequently (20% of trials) or in a frequency similar to that of a response-congruent word (such as the word “RED” presented in red). Classically, responses for incongruent stimuli are slower than responses for congruent stimuli; however, as the proportions of incongruent words increases, reaction time for these words decreases and approaches that of congruent words (Logan & Zbrodoff, 1979). This “Proportion Congruent” (PC) effect is generally considered evidence in favor of increased availability of attentional control as the experimental proportion of control-demanding stimuli increases (Bugg & Crump, 2012), and has been demonstrated even when in/congruency was based on semantic aspects of stimuli such as higher-level category (Blais et al., 2015; see also Hutchison, 2007). Our results bear strong conceptual resemblance to the PC findings - as the proportion of conceptually novel stimuli in a specific list increased, responses became faster, suggesting increased availability of attentional control.

Whereas the effect of increased control on response latencies is relatively well established, recent evidence suggests that the application of attentional inhibitory control

processes leads to reduced memory performance (inhibition-induced forgetting; Chiu & Egner, 2015; Mayo, Schul, & Rosenthal, 2014). In their experiments, avoiding a response or correctly negating an incorrect feature of an entity, two actions which require increased control, resulted in reduced memory rates for the items which were associated with the control-demanding action. Thus, our effects could also be the product of an integration between the PC and inhibition-induced forgetting accounts, whereby increased application of attentional control (which results from increased experimental proportions of novel events) gradually leads to worse mnemonic performance for these events.

Prior knowledge and novelty: Distinct effects?

Whereas mnemonic performance for novel events varied across experimental proportions, memory rates for familiar events remained stable throughout the different experimental proportions. Response latencies for familiar stimuli were affected by the proportion manipulation only when they were infrequent (5%); in all other proportions they were associated with comparable RTs. The relatively stable performance for familiar stimuli proposes that familiarity evokes a robust response which is subject to little interference from contextual factors such as experimental proportion.

One possible interpretation of these findings would portray familiar stimuli (i.e., knowledge we already own) as the input which our cognitive system is tuned to anticipate - the default prediction of the system (in line with a predictive coding framework; Bar, 2007; Bruner & Postman, 1949; Kanai et al., 2015). A familiar stimulus evokes a standard well-rehearsed processing routine. On the other hand, novel stimuli are unexpected and constitute a violation of predictions that necessitates a deviation from the default route. Consequently, novelty is associated with impeded responses and increased control.

Regardless of the specific processing mechanisms at play, the exclusivity of effects of experimental proportions on novel events (while familiar events were indifferent to it) suggests that novelty and familiarity require partially distinct processing mechanisms. Based on our results, we suggest that online processing and subsequent memory for familiar stimuli are based on a default operation setting of our cognitive system. As our daily life summons frequent encounters with familiar events, we are well trained in incorporating them into memory. In contrast, novelty is rarely encountered; it constitutes a violation of expectations and requires additional processes or mechanisms for successful integration in episodic (or other) memory. These findings coincide nicely with recent demonstrations of separate neural mechanisms supporting novelty and familiarity (Hawco & Lepage, 2014; Kafkas & Montaldi, 2014; Reggev et al., 2016). The reliance on different or additional mechanisms could explain the specific sensitivity of novelty to experimental factors such as distinctiveness. The precise optimal definition of novelty and the utilization of similar or different mechanisms for different types of novelty remain, for now, questions for future explorations.

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TABLES

Table 1. Percent correct for incidental encoding task for Experiments 1 and 2, averaged across participants, as a function of the experimental proportion of novel events (a between-participants condition) and of stimuli conceptual status (within-participant). Parentheses indicate standard error of the mean.

<i>Exp. Prop. (Novelty)</i>		2.5%	7.5%	12.5%	50%	(-)	
Exp. 1	Familiar	0.97 (0.01)	0.94 (0.02)	0.96 (0.01)	0.94 (0.02)	(-)	
	Novel	1.00 (0.00)	1.00 (0.00)	0.96 (0.02)	0.96 (0.01)	(-)	
<i>Exp. Prop. (Novelty)</i>		(-)	5%	22%	50%	78%	95%
Exp. 2	Familiar	(-)	0.9 (0.02)	0.95 (0.01)	0.93 (0.03)	0.92 (0.01)	0.91 (0.02)
	Novel	(-)	0.9 (0.02)	0.93 (0.01)	0.93 (0.02)	0.95 (0.01)	0.94 (0.01)

Table 2. Percent “old” responses at recognition memory test for Experiments 1 and 2, averaged across participants, as a function of the experimental proportion of novel events (a between-participants condition) and of foil or stimuli conceptual status at encoding (within-participant). Parentheses indicate standard error of the mean.

<i>Exp. Prop. (Novelty)</i>		2.5%	7.5%	12.5%	50%	(-)	
Exp. 1	Familiar	0.77 (0.03)	0.82 (0.02)	0.77 (0.03)	0.8 (0.02)	(-)	
	Novel	0.75 (0.07)	0.78 (0.04)	0.8 (0.04)	0.66 (0.03)	(-)	
	Foil	0.08 (0.01)	0.09 (0.02)	0.12 (0.02)	0.13 (0.02)	(-)	
<i>Exp. Prop. (Novelty)</i>		(-)	5%	22%	50%	78%	95%
Exp. 2	Familiar	(-)	0.65 (0.03)	0.67 (0.04)	0.64 (0.03)	0.66 (0.03)	0.68 (0.04)
	Novel	(-)	0.67 (0.03)	0.65 (0.05)	0.53 (0.04)	0.5 (0.04)	0.54 (0.03)
	Foil	(-)	0.19 (0.03)	0.23 (0.04)	0.14 (0.02)	0.16 (0.02)	0.17 (0.02)

Table 3. Response latencies for incidental encoding task for Experiments 1 and 2, averaged across participants, as a function of the experimental proportion of novel events (a between-participants condition) and of stimuli conceptual status (within-participant). Foils were neutral in respect to familiarity/novelty (see main text for details). Parentheses indicate standard error of the mean.

<i>Exp. Prop. (Novelty)</i>		2.5%	7.5%	12.5%	50%	(-)	
Exp. 1	Familiar	1127 (46)	1148 (43)	1250 (26)	1134 (32)	(-)	
	Novel	1413 (58)	1428 (58)	1444 (54)	1264 (40)	(-)	
<i>Exp. Prop. (Novelty)</i>		(-)	5%	22%	50%	78%	95%
Exp. 2	Familiar	(-)	1246 (56)	1162 (50)	1206 (44)	1207 (31)	1459 (48)
	Novel	(-)	1594 (65)	1358 (43)	1355 (51)	1215 (39)	1272 (53)

778 **FIGURES**

779 Figure 1. Overview of task design in Experiments 1 and 2. Bottom panel illustrates the
 780 between-participants experimental proportion manipulation.

782 Figure 2. Across-participants mean recognition rates for items encoded in a familiar or novel
783 context in Experiment 1 (40 items). The horizontal axis denotes the experimental proportion
784 of novel events. Error bars denote standard error of the mean.

785

786 Figure 3. Across-participants mean reaction time at incidental encoding phase for items
 787 encoded in a familiar or novel context in experiment 1 (40 items). The horizontal axis denotes
 788 the experimental proportion of novel events. Error bars denote standard error of the mean.
 789 See main text for significance testing approximation.

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794 Figure 4. Across-participants mean recognition rates for items encoded in a familiar or novel
 795 context in Experiment 2 (180 items). The horizontal axis denotes the experimental proportion
 796 of novel events. Error bars denote standard error of the mean. Recognition rates for
 797 Experiment 1 are included in the inset for ease of comparison.