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The influence of prior knowledge on the formation of detailed and durable memories

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ABSTRACT

Prior knowledge often improves recognition, but its relationship to the retrieval of memory detail is unclear. Resource-based accounts of recognition suggest that familiar stimuli are more efficiently encoded into memory, thus freeing attentional resources to encode additional details from a study episode. However, schema-based theories would predict that activating prior knowledge can lead to the formation of more generalized representations in memory. Across a series of four experiments, we examined the relationship between prior knowledge and memory for extrinsic context (i.e., extra-item details from the surrounding study episode) and intrinsic context (i.e., memory for the precise intra-item features of the studied target itself). Familiar stimuli (famous faces and popular foods/beverages) were associated with better memory for extrinsic context, operationalized as Remember responses and objective source memory accuracy. Self-reported degree of prior knowledge associated with a given image was also predictive of this effect. Prior knowledge improved recognition memory during a surprise delayed recognition test, even under conditions in which study was unintentional, supporting the idea of efficient encoding. Critically, in a paradigm in which recognition required the correct rejection of highly perceptually similar lures, prior knowledge was associated with more false alarms. Our results suggest that stimuli associated with prior knowledge are indeed efficiently encoded into memory, freeing more attentional resources to encode extrinsic context. This benefit, however, may come at the cost of memory precision for the item itself. By examining extrinsic and intrinsic context separately, we demonstrate that resource and schema-based theories provide complementary accounts of how prior knowledge influences memory detail.

Introduction

Prior knowledge supports our ability to form new memories. For example, item memory is markedly better for familiar as compared to unfamiliar faces (Bäckman, 1991; Bird, Davies, Ward, & Burgess, 2011; Klatzky & Forrest, 1984; Yarmey, 1971). In many of these experiments, the presence of prior knowledge was incidental to the recognition memory decision and yet studied faces were much more likely to be accurately recognized if they were of individuals that were already familiar to the participants (e.g., famous actors). This benefit of prior knowledge on item memory is by no means limited to faces. Studies of expertise have used a wide range of stimuli to demonstrate a positive relationship between knowledge and item recognition (e.g., *chess*: Goldin, 1979; *baseball*: Chiesi, Spilich, & Voss, 1979; *medical images*: Evans et al., 2011; Myles-Worsley, Johnston, & Simons, 1988; *own-race effects*: Goldstein & Chance, 1980; *mountain scenes*: Kawamura, Suzuki, & Morikawa, 2007). Functional neuroimaging experiments also have demonstrated clear differences in the brain when prior knowledge is available as opposed to when it is not (Bar, Aminoff, & Ishai, 2008; Bein, Reggev, & Maril, 2020; Brod, Lindenberger, & Shing, 2017; Brod, Werkle-Bergner, & Shing, 2013; Chen et al., 2016; Gobbini & Haxby, 2007; Liu, Grady, & Moscovitch, 2016; Poppenk, Moscovitch, & McIntosh, 2016; van Kesteren, Ruiter, Fernández, & Henson, 2012; van Kesteren, Rijpkema, Ruiter, Morris, & Fernandez, 2014; van Kesteren, Rijpkema, & Ruiter, 2010). Overall, prior knowledge appears to be an important determinant of learning and memory.

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Despite a pronounced item memory benefit, it remains unclear whether prior knowledge is associated with the formation of more *detailed* memory representations. To operationalize memory detail, we turn to the distinction between *intrinsic* and *extrinsic* context described by Ecker, Zimmer, and Groh-Bordin (2007a) and Mulligan (2011). Extrinsic context refers to memory for extra-item details from the encoding context (i.e., source memory), such as the background on which a stimulus was presented, which stimuli were spatially or temporally adjacent to the target item, or even what the individual's thoughts and mental states were at encoding. *Intrinsic context* refers to the granularity of intra-item details in memory, or the level of grain at which we are able to encode the physical properties of the stimulus itself, ranging from detail-impoverished to high-fidelity perceptually-rich memory representations. These two dimensions of memory detail have been posited to rely on separable types of representations in memory (Ecker et al., 2007a; Ecker, Zimmer, & Groh-Bordin, 2007b), are differentially impacted by certain encoding manipulations (e.g., generation effect; Mulligan, 2011; Mulligan, Lozito, & Rosner, 2006), are associated with different patterns of performance in old age (Spencer & Raz, 1995; Troyer, Winocur, Craik, & Moscovitch, 1999) and, therefore, provide a concrete operationalization of memory detail for our purposes. Though memory detail certainly contributes to the item recognition benefits associated with prior knowledge (e.g., via memory strength; Wixted, 2007), item recognition often employs binary old-new decisions that fail to measure either type of detail directly. Therefore, it remains an open question to what extent prior knowledge boosts memory source and detail in addition to overall recognition.

Should prior knowledge afford the formation of more detailed memories? Resource-based accounts contend that prior knowledge benefits memory as familiar stimuli are easier to chunk and thus less demanding on limited attentional resources at encoding (DeWitt, Knight, Hicks, & Ball, 2012; Diana & Reder, 2006; Popov & Reder, 2020; Reder et al., 2013). If familiar stimuli require less attentional resources than unfamiliar stimuli, more resources should also be available to encode additional details from the study episode. Studies of associative and source memory are consistent with this hypothesis, demonstrating that the more familiar we are with a stimulus, whether via pre-experimental knowledge (Brandt, Cooper, & Dewhurst, 2005; DeWitt et al., 2012; Horry, Wright, & Tredoux, 2010; Liu et al., 2016; Long, Prat, Johns, Morris, & Jonathan, 2008; Long & Prat, 2002; Reder et al., 2013) or repeated exposure within an experiment (Reder, Liu, Keinath, & Popov, 2016), the more likely we are to bind the studied target to its context or form new associations. Studies of visual working memory also show that we are better able to hold perceptual details in mind for stimuli that are familiar (e.g., upright faces) as compared to unfamiliar ones (e.g., inverted faces) (Curby & Gauthier, 2007; Curby, Glazek, & Gauthier, 2009; Jackson & Raymond, 2008; Scolari, Vogel, & Awh, 2008). Also, familiar stimuli are broadly less demanding on working memory resources (Brady, Störmer, & Alvarez, 2016), again consistent with predictions from resource-based accounts (see also, Shen, Popov, Delahay, & Reder, 2018).

The memory benefits of prior knowledge also have been attributed to schemas. According to schema theory, stimuli associated with prior knowledge activate related knowledge structures into which new learning can be assimilated (Alba & Hasher, 1983; Bein, Trzewik, & Maril, 2019; Bransford & Johnson, 1972; Ghosh & Gilboa, 2014; Gilboa & Marlatte, 2017). Activating existing knowledge structures can support new learning, but this benefit tends to be specific to information that is consistent with existing knowledge. Information that is inconsistent with schemas, on the other hand, can cause interference and is more difficult to learn (McClelland, 2013; McClelland, McNaughton, & O'Reilly, 1995). Neural models of schema-based learning further posit that the activation of existing knowledge structures can down-regulate hippocampal activity and make it less likely that we encode new details (van Kesteren et al., 2012). Inconsistent information, on the other hand, elicits a prediction error which upregulates hippocampal encoding of details from our surroundings (Bein, Duncan, & Davachi, 2020; Kumaran & Maguire, 2007; van Kesteren et al., 2012). Such a mechanism should also have general consequences for learning of arbitrary details from a study episode. For example, when studying a familiar stimulus in a recognition memory paradigm, one should expect it to evoke prior knowledge while simultaneously failing to elicit a prediction error, amounting to a more generalized and detail-impoverished memory. A similar generalization effect can be observed when participants have some way of labelling a target item during study (e.g., a name), again resulting in learned representations that are less context-specific than when they are studied without a label (Armann, Jenkins, & Burton, 2016; Schwartz & Yovel, 2016). This kind of abstraction process is central to many schema-based accounts of learning and memory, in which activating a knowledge framework allows for the robust encoding of the central elements of an episode while simultaneously reducing the saliency of idiosyncratic details that are less likely to occur again (Alba & Hasher, 1983; Gilboa & Marlatte, 2017; Sekeres et al., 2016).

Resource-based and schema theories differ in their predictions about how prior knowledge should affect memory detail. The two theories, however, may complement one another if we consider the constituent elements of extrinsic and intrinsic context separately. Specifically, the generalizing effect associated with schemas may be specific to intrinsic context. Take the example of studying a famous face in the context of a recognition memory experiment. At encoding, a famous face may evoke general schematic associations (e.g., its name, its typical appearance, its semantic or autobiographical associations, etc.). By activating these associations, the study episode may be easily recoded as a meaningful chunk of experience – requiring fewer resources to encode and, in turn, leaving more attentional resources available to encode extrinsic context from the study episode (e.g, DeWitt et al., 2012; Diana & Reder, 2006; Popov & Reder, 2020; Reder et al., 2013). This efficient encoding process, however, may lead to a loss of intrinsic context in memory. For example, if famous faces trigger existing representations of the appearance of a given person, this schematic information may interfere with the encoding of their particular appearance in a new study episode (e.g., McClelland, 2013; van Kesteren et al., 2012). In a related idea to interference, the process of chunking itself may be associated with information loss depending on how it is operationalized. Chunking is the process of recoding multiple features (e.g., a study episode) into a single unit in memory (de Groot, 1965; Gobet et al., 2001; Gobet & Simon, 1998; Miller, 1956) and consequently can be thought of as an example of data compression. Data compression schemes are commonly divided into two classes: lossless vs. lossy compression. Lossless compression allows for the perfect reconstruction of the original data from its compressed form, while lossy compression permits information loss to allow for more substantial compression (Sayood, 2003; see also Nassar, Helmers, & Frank, 2018; Norris & Kalm, 2018). Compression exploits the redundancy in an input stream. Simple, structured, low-dimensional inputs can be easily compressed and reconstructed from memory (e.g., Mathy & Feldman, 2012), while complex multifeatured stimuli like faces may be difficult to compress without losing some stimulus information. Therefore, the efficient chunking of familiar faces, for example, may come at the cost of a more generalized representation of the face itself (i.e., loss of intrinsic context) despite facilitating the encoding of extrinsic context from the study episode. Unfamiliar faces, which lack associations with prior knowledge, will instead be more difficult to chunk and thus may maintain their intra-item fidelity without leaving enough resources available to encode extra-item details. Considering the constituent elements of memory detail separately allows for the possibility that prior knowledge simultaneously facilitates the encoding of extrinsic context while impairing the encoding of intrinsic context, thus acting as a potential bridge across resource and schema-based accounts. To our knowledge, no work has yet compared the influence of prior knowledge on these separable aspects of memory detail.

In a series of 4 experiments, we tested this possibility by examining how prior knowledge related to extrinsic and intrinsic context during recognition. Experiments 1–3 focus on extrinsic context and Experiment 4 tests intrinsic context. In Experiment 1, participants encoded a series of famous and non-famous faces. Memory for extrinsic context was assessed using subjective and objective measures of source memory. To provide a point of comparison for prior knowledge, we also included a manipulation of how long the faces were onscreen during encoding (1 or 4s). Experiment 2 examined whether participants' self-reported degree of familiarity with famous faces was able to predict benefits in extrinsic context. Experiment 3 generalized our findings to another class of stimuli: branded foods and beverages. Finally, Experiment 4 examined intrinsic context to directly test whether prior knowledge was associated with the formation of higher (or lower)-grain representations of the studied stimulus itself. To this end, we modified our paradigm based on the mnemonic similarity task (MST) (Kirwan & Stark, 2007; Stark, Yassa, Lacy, & Stark, 2013), to test whether prior knowledge would continue to support accurate recognition even when it required the correct rejection of highly-similar lures.

In addition to improving performance on an immediate memory test, encoding information into pre-existing knowledge structures can facilitate neocortical learning and consolidation. Prior knowledge facilitates the formation of durable memories more quickly than expected by standard hippocampal learning of novel information (McClelland, 2013; Sharon, Moscovitch, & Gilboa, 2011; Tse et al., 2007; for related discussions, see Antony, Ferreira, Norman, & Wimber, 2017; Gilboa & Marlatte, 2017). Benefits of prior knowledge on memory consolidation have also been reported to extend beyond intentional learning, carrying into incidental learning (e.g., Wattenmaker, 1999). Therefore, we also examined the role of prior knowledge on the formation of durable memories in Experiment 2 and 3 via a surprise delayed recognition test.

To preview our results, we observed a reliable benefit of prior knowledge on the formation of detailed memories, using both subjective and objective measures of extra-item detail. This effect was greater than that of encoding duration and generalized across both stimulus classes. The degree of prior knowledge associated with a stimulus predicted the likelihood of recollecting extrinsic context and the benefit of prior knowledge persisted into delayed recognition, even under conditions of incidental encoding. Prior knowledge, however, was associated with more false alarms to highly perceptually similar lures – suggesting a loss of intrinsic context when encoding familiar stimuli. Overall, our results show that the availability of prior knowledge at encoding supports extrinsic context at the cost of intrinsic context – providing novel evidence for an important link between resource and schema-based accounts of knowledge-driven learning.

Experiment 1

In Experiment 1, we sought to replicate the relationship between prior knowledge and memory for extrinsic context. To this end, we presented participants with famous and non-famous faces in the context of a recognition memory experiment using the Remember-Know paradigm (Tulving, 1985). Extrinsic context was operationalized as Remember hits and objective source memory accuracy (i.e., memory for the colour of a border presented around the face at study). We also manipulated encoding duration (1 vs 4 s) for famous and non-famous faces alike, allowing us to examine how prior knowledge influences memory detail as compared to prolonged exposure.

Methods

Participants

Thirty-one young adults between 19 and 30 years of age participated in the experiment. Participants were recruited from the University of Toronto and surrounding areas and were compensated at a rate of $10/hour with an average testing session lasting 2 h. Sample size was chosen based on previous studies of prior knowledge and memory (Bird et al., 2011; Brandt et al., 2005; Liu et al., 2016; Poppenk, Köhler, & Moscovitch, 2010). Seven participants did not meet our inclusion criteria for the final sample and were excluded from subsequent analyses [i.e., they did not recognize at least 60% of famous faces/correctly reject at least 60% of non-famous faces (n = 2), or limited use (<5) of either the Remember or Know responses (n = 5)]. Our final sample included 24 participants (years of age: $M = 22.7$, $SD = 2.6$; years of education: $M = 15.8$, $SD = 1.2$; $n_{female} = 19$). Sample sizes for subsequent experiments were chosen based on power analyses performed using effect sizes from Experiment 1. All studies were approved by the Research Ethics Board at the University of Toronto and informed consent was given by each participant before participating.

Stimuli

Images were obtained from the Internet using Google image search to create a pool of 400 stimuli. Two-hundred images were of famous celebrities and 200 were of non-famous people. Both famous and non-famous pools were balanced for sex, with 100 male and 100 female images each. Faces were neutral to slightly positive in expression. Non-famous faces were each manually matched for age, race, and other distinctive features with a corresponding famous face to ensure no overall differences across stimulus pools. Furthermore, images of non-famous people were selected to be "famous-like", such that they were often found on various modelling agency websites and their image quality was comparable to those of the famous celebrities. The faces were manually centered and cropped from the full image using an oval frame in Adobe Photoshop and resized to 475×595 pixels. Images were set to black and white and their luminance was matched using SHINE toolbox (Willenbockel et al., 2010) and custom scripts in Matlab (MathWorks, Natick, MA, USA). A scrambled version of each face was also generated using custom scripts in Matlab (MathWorks, Natick, MA, USA), such that each image was divided into 5-pixel clusters and then randomly shuffled. These scrambled images were used for null trials.

An online pilot study was conducted to collect normative subjective ratings on the stimuli. All 400 face stimuli were incorporated into a survey via Qualtrics (Qualtrics, Provo, Utah, USA), and 7 separate ratings were collected for each face. The 7 rating tasks included in the survey were as follows: 1) recognition and nameability, and 5-point ratings of 2) fame, 3) facts known about the person pictured, 4) personal memories associated with the person pictured, 5) emotionality, 6) facial expression, and 7) attractiveness (for details, see Supplementary Material: Section 1). The survey was administered in-lab and online using Amazon's Mechanical Turk (Amazon, Seattle, WA, USA), and included a total of 225 participants between the ages of 19 and 28. Participants were all either in Canada or the USA when completing the survey and gave their consent before participating. Each participant was presented with a randomly selected subset of 100 faces, 50 famous and 50 non-famous, and was required to perform all seven ratings per face. One catch trial per rating task was included instructing participants to make a specific rating, serving as a quality-check to ensure all participants were following instructions. Data from participants with an incorrect catch trial in any of the seven rating tasks were excluded entirely from all subsequent analyses. Ratings from 190 participants survived this strict exclusion criterion, which amounted to ratings from 47 to 58 participants per face.

Only famous faces that were reliably recognized across participants were included in the stimulus pool for the main recognition experiments. To isolate the most reliably recognized faces, recognition was operationalized as: (% of participants who recognized a given face) – (% of participants who did not recognize a given face). Positive values indicate that the majority of participants recognized the face, while negative values indicate that the majority of participants did not. The final stimulus pool consisted of 128 faces that were the most recognizable ($M = 68\%$, $SD = 20\%$) and their age and race matched non-famous counterparts ($M = -78\%$, $SD = 12\%$) for a total of 256 faces. Both famous and non-famous stimulus pools used for recognition were balanced in terms of sex ($n_{male} = 64$, $n_{female} = 64$, for both famous and non-famous pools). Independent samples t-tests were used to compare average ratings across the final famous and non-famous stimulus pools, with Bonferroni adjusted p-values for multiple comparisons by multiplying the uncorrected p-values by the total number of comparisons (i.e., 6). The famous and non-famous faces were comparable in terms of attractiveness ($M_{famous} = 2.8$, $M_{non\text{-}famous} = 2.7$; $t(254) = 2.25$, $p > .1$, *Cohen's d* = .28), but robustly differed in terms of fame ($M_{famous} = 3.8$, $M_{non\text{-}famous} = 1.4$; $t(254) = 39.9$, $p < .0001$, *Cohen's d* = 4.99), facts known ($M_{famous} = 3.3$, $M_{non\text{-}famous} = 1.3$; $t(254) = 44.69$, $p < .0001$, *Cohen's d* = 5.59), personal memories ($M_{famous} = 2.6$, $M_{non\text{-}famous} = 1.2$; $t(254) = 28.23$, $p < .0001$, *Cohen's d* = 5.59), and emotionality ($M_{famous} = 2.7$, $M_{non\text{-}famous} = 1.7$; $t(254) = 36.71$, $p < .0001$, *Cohen's d* = 3.53). These robust differences were by design, as the measures with large differences were on rating scales that tapped into aspects of prior knowledge. Relative to prior knowledge, a modest difference was also found in facial expression ($M_{famous} = 2.6$, $M_{non\text{-}famous} = 2.3$; $t(254) = 3.85$, $p = .0009$, *Cohen's d* = .48), suggesting the famous faces were perceived to be slightly more expressive.

Procedure

For a schematic overview of Experiment 1, see Fig. 1. Participants made Remember-Know recognition judgements (Tulving, 1985) to a total of 128 famous and 128 non-famous faces (96 targets, 32 foils each). Participants select the "Remember" option (R) if their recognition is accompanied by recall of contextual information (i.e., source memory) from the study episode. "Know" (K) is selected if recognition is not accompanied by any contextual information from study. The specific instructions used for this experiment can be found in the Supplementary Material: Section 2, as per the suggestions of Migo, Mayes, and Montaldi (2012). Dual-process models conceptualize recognition as a composition of two signals: recollection and familiarity (Mickes, Wais, & Wixted, 2009; Wixted & Stretch, 2004; see also Tulving, 1985). Recollection reflects the likelihood that recognition is accompanied by additional recall of idiosyncratic details from the encoding context. Familiarity instead reflects an item-specific memory signal, contributing to recognition in the absence of any recall of additional contextual information. The degree to which these two signals are separate remains debated (Diana, Reder, Arndt, & Park, 2006; Moran & Goshen-Gottstein, 2015; Slotnick, 2010; Slotnick, Jeye, & Dodson, 2016; Wixted & Stretch, 2004; Yonelinas, 2002; Yonelinas, Aly, Wang, & Koen, 2010), however, the Remember responses provide a useful subjective index of the extent to which recognition is accompanied by the re-experiencing of source details from the study episode.

In order to probe overall recognition memory performance, we calculated d′, or the standardized difference between the proportion of accurately recognized old trials (hits) and the proportion of new trials that were incorrectly recognized (false alarms; FA). Note that the new trials in our experiment could be either famous or non-famous faces, and thus our design crossed prior knowledge for both the studied and unstudied faces, allowing for an estimate of recognition accuracy that is unbiased by prior knowledge. As a general note, we do not believe the Remember response is a process-pure measure of recollection, but by using a combination of the Remember-Know procedure and source memory accuracy, we argue that we can accurately capture extra-item source details in memory and thus can quantify the relationship between prior knowledge and detailed memory formation.

The procedure in this particular paradigm consisted of 8 blocks, each of which contained a study and recognition phase. Prior knowledge was manipulated at the block level such that 4 of the blocks were entirely composed of famous stimuli and the remaining 4 blocks, of non-famous stimuli, in a fixed interleaved order which was counterbalanced across participants. During each encoding phase, participants explicitly studied a pseudorandom sequence of 24 face trials. Each trial began with a green fixation cross presented for 500 ms, followed by a face stimulus presented centrally on screen within a red- or blue-coloured rectangle. Half of the face stimuli were presented for 1 s and half for 4 s to provide a manipulation of encoding duration, followed by an inter-trial interval ranging between 1500 and 2750 ms ($M = \sim 2$s). Participants were asked to study each face in as much detail as possible as their memory would be tested immediately after each study phase. No explicit response was required during study. Participants were also instructed that each block was independent from the others and contained unique face stimuli.

In addition to the target face trials, 12 additional null trials were also interspersed during the study phase. Null trials consisted of a scrambled

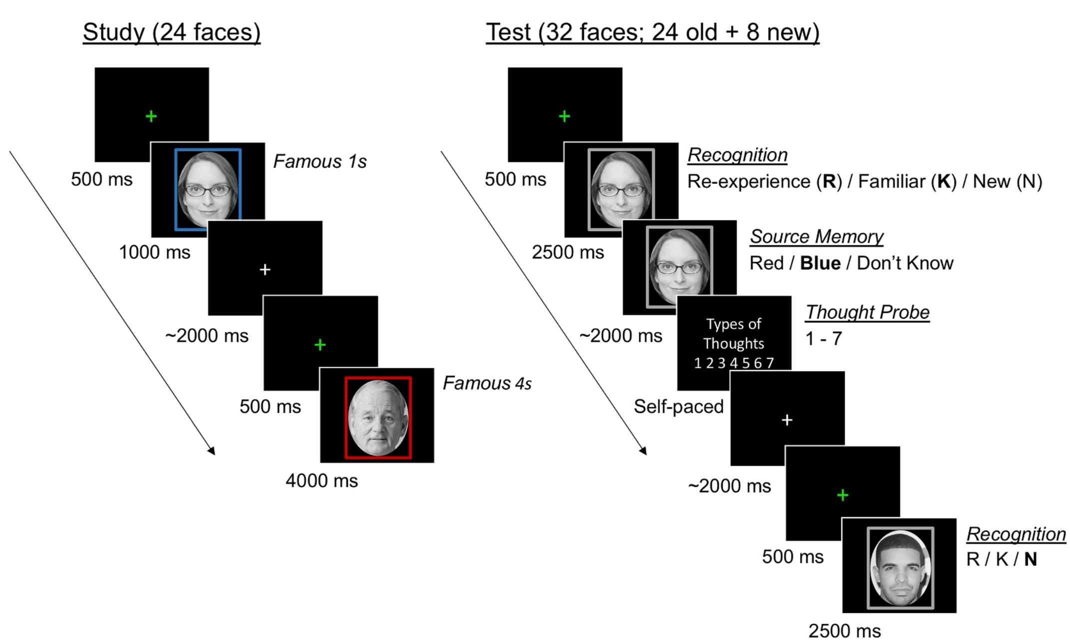

Fig. 1. A schematic example of one study-test block from Experiment 1. Immediate recognition in Experiment 2 was almost identical to the above depiction, except thought probes were excluded. In this example, bold font indicates the correct response. For details, see Procedure.

face stimulus from the experiment, 6 of which were presented for 1 s and 6 for 4 s. Null trials were not to be encoded and were used to make the paradigm comparable to a separate experiment conducted with functional magnetic resonance imaging (fMRI). These trials were not relevant to the behavioural paradigm and will not be discussed further.

The first recognition trial was presented 20 s after the termination of the last study trial. During each recognition phase, participants were presented with a pseudorandom sequence of 32 faces. 24 of the faces were from the previous study list and 8 were novel foils (i.e., old/new ratio of 75/25). Again, each trial began with a green fixation cross presented for 500 ms, followed by the face stimulus presented centrally onscreen within a grey-coloured rectangle. Each face was presented for 2.5 s during which time participants were required to make a Remember (R), Know (K), or New (N) response using the keyboard. Participants used both hands to make responses; the index and middle finger of one hand were used to respond R or K and the index finger of the other to respond N. The mapping of hand to response option was counterbalanced across participants. Note that participants were given the labels "re-experienced" and "familiar" in lieu of Remember and Know across all experiments (see Fig. 1). This was done to more clearly map the subjective experience of each response to their label, which we have anecdotally found to improve our participants ability to comprehend this meta-cognitive distinction. If the participant indicated the image was from the previous study list (i.e., R or K), it immediately prompted the completion of two additional self-paced memory judgements. The first was a source memory judgement in which participants indicated the colour of the rectangular border presented with the face during study from the onscreen options: "Red", "Blue", or "Don't Know". Source memory provided a crucial objective estimate to accompany our subjective Remember responses by testing whether a specific dimension of contextual information from the study episode (i.e., border colour) accompanied recognition. The second was a subjective thought-probe that sought to provide supplementary insight into the kinds of thoughts that accompanied recognition. A detailed description of the thought probes and their results can be found in Supplementary Material: Section 3–4. Note: both source memory and thought probes only followed trials in which the participant indicated the face was indeed studied. If a participant pressed "New" in response to a face, it immediately prompted the next recognition memory trial.

In addition to the studied target and novel foil recognition trials, 12 additional null scramble trials were also interspersed during the recognition phase. Participants were asked to press the new response key for these trials; null trials were not relevant to the behavioural paradigm and will not be discussed further.

After the 8 blocks of the task were completed, participants were briefly interviewed for ~5 min regarding their memory strategies. Lastly, participants were asked to perform a series of post-test fame ratings on the stimuli from the completed experiment. All 256 faces from the previous 8 blocks of the experiment (i.e., both studied targets and novel foils) were used for this rating task. Trials were self-paced and participants responded with the index fingers of each hand using the buttons Q or P on the keyboard with response mapping counterbalanced across participants. Each trial began with a 500 ms green fixation cross, followed by the presentation of a face in the centre of the screen. Participants were first required to indicate whether they believed the face was of a famous or non-famous individual, based on their personal experience. For faces judged as famous, participants were then required to indicate whether or not they could name the famous individual. On average, participants correctly classified 89% (SD = 12%) of the famous faces and 93% (SD = 10%) of the non-famous faces. These data suggest that the famous faces used in this experiment were highly recognizable, consistent with online norming. Final analyses were restricted to only include faces that were correctly recognized as either famous or non-famous in the post-test.

Participants were provided with detailed instructions regarding the experimental procedure before beginning the task to ensure optimal comprehension and compliance. Experimenters provided a detailed scripted explanation of the task procedure, definitions of "Remember" and "Know", and also a description of the thought-probe labels (see Supplementary Material: Section 2). Participants were required to provide the experimenter with an adequate explanation of the R-K distinction and the thought-probe categories, in their own words, before they were permitted to continue. Participants also performed a practice run of the experiment, which consisted of studying a reduced list of 12 non-famous faces, half of which were presented for 1 s and half for 4 s. Recognition trials consisted of 16 faces, 12 from the study list and 4 novel foils. Participants were given feedback for recognition and source memory during the practice phase. No faces from the practice run were included in the final experiment.

Analyses

All statistical analyses were conducted using R (R Core Team, 2020). Repeated measures ANOVAs were implemented using the *ez* package (Lawrence, 2016). Effect sizes were reported using generalized η^2 or Cohen's *d* where appropriate.

Results

All data are publicly available on the Open Science Framework (https://osf.io/fqrhj/).

Prior knowledge improves overall recognition

Overall recognition accuracy was operationalized using d′, or the standardized proportion of accurately recognized studied targets minus the standardized proportion of false alarms to novel foils (i.e., z(hits) – z(false alarms)), per participant. This characterized discriminability in overall recognition while collapsing over subjective distinctions in recognition quality (i.e., Remember or Know). The effect of prior knowledge and encoding duration on recognition d′ was measured using a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) repeated-measures ANOVA (see Fig. 2A). Significant main effects of prior knowledge [$F(1,23) = 39.78$, $p < 0.0001$, $\eta^2_{G(Generalized)} = .25$] and encoding duration [$F(1,23) = 30.02$, $p < 0.0001$, $\eta^2_G = .018$] were observed. Presence of prior knowledge and a longer encoding opportunity during study both improved subsequent recognition accuracy, but prior knowledge produced the larger accuracy benefit. The interaction between prior knowledge and encoding duration was not statistically significant [$F < 1$].

Prior knowledge facilitates recognition via Remember hits

To determine whether the benefit in overall recognition was driven by a subjective measure of extrinsic context (i.e., Remember responses), we examined Remember and Know response rates for old (i.e., hits) and new trials (i.e., false alarms) separately. First, hit rates were examined using a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) × 2 (response type: Remember, Know) repeated-measures ANOVA (see Fig. 2B). Interactions between prior knowledge and encoding duration [$F(1,23) = 5.05$, $p = 0.034$, $\eta^2_G = .001$], prior knowledge and response type [$F(1,23) = 7.41$, $p = 0.012$, $\eta^2_G = .067$], and encoding duration and response type [$F(1,23) = 13.54$, $p = 0.0012$, $\eta^2_G = .005$] reached significance. Interactions were unpacked using paired t-tests. The interaction between prior knowledge and encoding duration was driven by a larger effect of fame in the 1 s [$t(23) = 7.6$, $p < .0001$, *Cohen's d* = 0.71] as compared to the 4 s condition [$t(23) = 5.5$, $p < .0001$, *Cohen's d* = 0.58] when averaging across Remember and Know trials. The interaction between prior knowledge and response type revealed that the effect of prior knowledge on recognition accuracy was driven by Remember [$t(23) = 3.98$, $p = .0006$, *Cohen's d* = 0.50] as opposed to Know trials [$t(23) = -1.06$, $p = .30$, *Cohen's d* = −0.13].

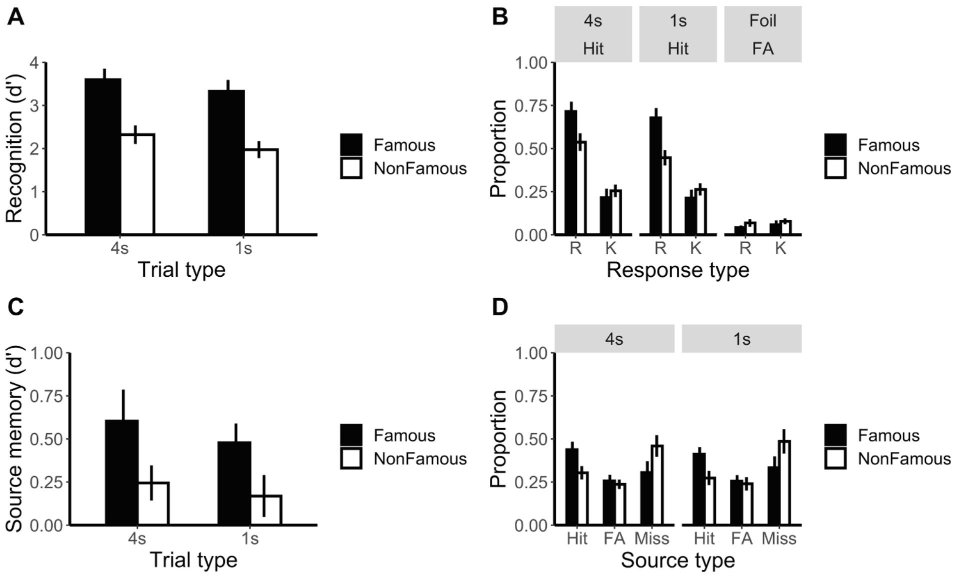

Fig. 2. Results from Experiment 1: Prior knowledge benefits overall recognition and memory for extrinsic context, more so than extended study opportunity. Memory for extra item detail was operationalized using subjective (Remember) and objective source memory accuracy. **(A)** Effect of prior knowledge (i.e., famous, non-famous) and encoding duration (1 s, 4 s) on overall recognition accuracy [i.e., d′ = z(hits) – z(false alarms)]. **(B)** Overall recognition expressed as proportion of hits and false alarms for Remember and Know responses, separately. Better recognition for famous faces is driven by a boost in Remember hits. **(C)** Effect of prior knowledge a encoding duration on source memory accuracy [i.e., d′ = z (source hits) – z(source false alarms)]. **(D)** Source memory accuracy broken down into hits (accurate source), false alarms (source misattribution), and misses (forgotten source). Proportion in the case of source memory is based on the total of trials with correct item recognition only. Error bars represent standard error of the mean.

Finally, the interaction between encoding duration and response type revealed that encoding duration also modestly benefitted Remember [$t(23) = 5.26$, $p < .0001$, *Cohen's d* = .04] as opposed to Know trials [$t(23) = -0.27$, $p = .79$, *Cohen's d* = −0.002].

False alarm rates were also examined using a 2 (prior knowledge: famous, non-famous) × 2 (response type: Remember, Know) repeated-measures ANOVA (see Fig. 2B). There was a marginal main effect of prior knowledge [$F(1,23) = 3.28$, $p = 0.083$, $\eta^2_G = .015$], as famous faces were associated with fewer false alarms. All other effects failed to reach significance [$F < 1$]. Overall, the benefit of prior knowledge on recognition appeared to be driven by a boost in Remember hits, consistent with the idea that prior knowledge supports the encoding of extrinsic context.

Prior knowledge boosts source memory hits

We next examined an objective estimate of extrinsic context: the likelihood a participant could successfully recall the colour of the border surrounding the face at study. Subject-specific estimates of source memory were submitted to a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) repeated-measures ANOVA. First, source memory accuracy was calculated using d′, or the standardized proportion of accurately recognized trials in which border colour was correctly recalled minus the standardized proportion of accurately recognized trials in which border colour was incorrectly recalled (i.e., z (source hits) – z(source false alarms)). Note that chance was not 50% for these trials, as participants had 3 response options: "Red", "Blue" or "Don't Know", and were instructed to choose "Don't Know" if they were not sure. All "Don't Know" trials were considered misses and thus do not contribute to this analysis. A significant main effect of prior knowledge was observed [$F(1,23) = 8.47$, $p = 0.008$, $\eta^2_G = .064$], as recognition of famous faces was more likely to accompany accurate source memory for the border colour from study, consistent with the boost in subjective Remember responses (Fig. 2). No main effect or interaction with encoding duration was observed [$F < 1$].

For a more detailed sense of how prior knowledge affects memory for extrinsic context, source memory response rates were submitted to a 2 (prior knowledge: famous, non-famous) × 3 (response type: hit, false alarm, miss) repeated measures ANOVA. Note: a source *false alarm* is when a participant indicates the border colour is blue when it was red, or vice versa, while a *miss* is when participants fail to recall the border colour and select "Don't Know". A significant interaction between prior knowledge and response type was observed [$F(1,23) = 18.54$, $p < 0.0001$, $\eta^2_G = .059$]. Paired t-tests highlight that prior knowledge was associated with an increase in source hits [$t(23) = 4.54$, $p = 0.0002$, *Cohen's d* = 0.41], no effect on source false alarms [$t(23) = 1.33$, $p = 0.20$, *Cohen's d* = 0.03], and a reduction in source misses [$t(23) = -4.41$, $p = 0.0002$, *Cohen's d* = −0.19]. Overall, prior knowledge appears to boost source memory accuracy via hits as opposed to false alarms, in addition to a reduction in source forgetting.

Interim summary

Experiment 1 replicates previous work indicating that prior knowledge benefits item recognition (Bäckman, 1991; Bird et al., 2011; Klatzky & Forrest, 1984; Yarmey, 1971). Consistent with the resource hypothesis, we also found clear evidence that recognition is accompanied by better memory for extra item details, operationalized as Remember hits and objective source memory (Brandt et al., 2005; DeWitt et al., 2012; Horry et al., 2010; Long et al., 2008; Long & Prat, 2002; Reder et al., 2013). Longer encoding duration (4 vs 1 s) benefitted item recognition and Remember hits as well, though to a lesser degree than prior knowledge. Interestingly, encoding duration did not appear to benefit objective source memory accuracy, suggesting that pre-experimental familiarity is a more robust determinant of extrinsic context in memory as compared to study opportunity. This discrepancy between prior knowledge and encoding duration on extrinsic context is reminiscent of the effect of deep processing on recollection. Attending to the semantic meaning associated with a stimulus is more likely to produce recollection, as measured by Remember responses or objective source memory, as compared to attending to its surface-level perceptual features (Bower & Karlin, 1974; Craik, 2002; Craik & Lockhart, 1972; Yonelinas, 2002). Together, these results highlight the importance of semantic associations during encoding. When prior knowledge is available, the study episode can be readily parsed into meaningful chunks, leaving more resources available to encode extra-item details. However, when a stimulus is unfamiliar, chunking is more difficult (e.g., DeWitt et al., 2012; Diana & Reder, 2006; Reder et al., 2013) and longer study opportunity alone may be unable to compensate for the heightened demands on encoding resources.

Experiment 2

In Experiment 2, we sought to extend the previous results in two ways. First, if prior knowledge leaves more resources available to encode additional details from a study episode (Experiment 1), then it would follow that the amount of prior knowledge associated with a given stimulus should predict the likelihood of encoding additional extrinsic contextual details into memory. To this end, we collected subjective ratings of the degree of prior knowledge participants had, per stimulus, on a 5-point scale. With this measure, we were directly able to test our hypothesis that the degree of prior knowledge associated with a stimulus should predict the likelihood of recalling extrinsic context.

Second, we also sought to determine whether prior knowledge facilitated the formation of durable memories, persisting beyond immediate recognition. In the current paradigm, participants were exposed to 8 separate study-test blocks during which they learned 24 faces each, over the span of an hour, amounting to a total of 256 faces when including both targets and novel foils. If prior knowledge allows for better encoding, it follows that memory for the target itself may also prove durable and able to persist beyond immediate recognition. Neural evidence in line with this hypothesis suggests that prior knowledge facilitates neocortical learning and consolidation (McClelland, 2013; Sharon et al., 2011; Tse et al., 2007) affording the rapid formation of durable memories (for discussion, see Antony et al., 2017; Gilboa & Marlatte, 2017).

To explore these possibilities, we included a surprise delayed recognition test, in which all 256 faces (128 famous, 128 non-famous) from the previous 8 study-test blocks were presented alongside a small subset of entirely novel foils (16 famous, 16 non-famous). Included in the 256 target faces were both faces presented at study and faces presented as foils during immediate recognition, allowing us to measure delayed recognition performance of famous and non-famous faces under both intentional (viz. studied targets from immediate test) and incidental (viz. correctly rejected foils from immediate test) encoding conditions.

Methods

Participants

GPower v. 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to conduct a power analysis based on the main effect of prior knowledge on Remember hits in Experiment 1 ($\eta^2_G = .14$). The results of the power analysis indicated that a sample size of 19 would be required for find a significant effect with alpha = 0.05 and power = 0.9. To maintain a comparable sample size to Experiment 1, we aimed for a sample size of 48 participants, with 24 participants in each of the mixed and blocked conditions (see Procedure). Fifty-six young adults between 19 and 30 years of age participated in the experiment. Participants were recruited from the University of Toronto and surrounding areas and were compensated $10/hour. An average testing session lasted 2 h. Eight participants did not meet our inclusion criteria for the final sample and were excluded from subsequent analyses [i.e., did not recognize at least 60% of famous faces/correctly reject 60% of non-famous faces (n = 7), or limited use (<5) of the Remember or Know responses (n = 1)]. Our final sample consisted of 48 participants (years of age: $M = 22.1$, $SD = 2.1$; years of education: $M = 15.7$, $SD = 1.6$; $n_{female} = 41$).

Stimuli

Two-hundred and fifty-six faces (128 famous, 128 non-famous) from the final stimulus pool in Experiment 1 were used again in Experiment 2 (for details, see Methods for Experiment 1). 32 additional novel faces (16 famous, 16 non-famous; both balanced for sex: $n_{females} = 8$), from the overall 400 face stimulus pool, were included as novel foils in a surprise delayed recognition test, unique to Experiment 2. Based on the normative ratings collected online in our pilot study, the additional famous faces were more recognizable ($M = 45\%$, $SD = 7\%$) than the non-famous faces ($M = -76\%$, $SD = 12\%$), as expected. Also, the additional famous and non-famous faces were comparable in terms of average normative ratings of attractiveness ($M_{famous} = 2.8$, $M_{non\text{-}famous} = 2.8$; $t(30) < 1$) and facial expression ($M_{famous} = 2.5$, $M_{non\text{-}famous} = 2.3$; $t(30) < 1$), but robustly different in terms of fame ($M_{famous} = 2.9$, $M_{non\text{-}famous} = 1.4$; $t(30) = 18.40$, $p < 0.0001$, *Cohen's d* = 6.5), facts known ($M_{famous} = 2.8$, $M_{non\text{-}famous} = 1.3$; $t(30) = 15.46$, $p < 0.0001$, *Cohen's d* = 5.5), personal memories ($M_{famous} = 2.2$, $M_{non\text{-}famous} = 1.2$; $t(30) = 15.46$, $p < 0.0001$, *Cohen's d* = 5.5), and emotionality ($M_{famous} = 2.4$, $M_{non\text{-}famous} = 1.7$; $t(30) = 12.65$, $p < 0.0001$, *Cohen's d* = 4.5).

Procedure

Participants made Remember-Know judgements on 128 famous and 128 non-famous faces (96 targets, 32 foils each) in a nearly identical procedure to Experiment 1. The differences between the two paradigms will be highlighted below. For both encoding and retrieval phases within each of the 8 blocks, Experiment 2 used fully randomized trial orders as opposed to the pseudorandom sequences used in Experiment 1. This randomization removed any possibility that participants were able to notice potential structure in the trial order. Also, Experiment 2 manipulated prior knowledge using either a mixed (i.e., famous and non-famous stimuli presented in each block) or blocked design (i.e., famous and non-famous stimuli presented in separate blocks), across participants. Like Experiment 1, participants encoded a sequence of 24 faces in each block, but in the mixed design 12 of these faces were famous and 12 were non-famous. In addition, we included the encoding duration manipulation, such that 6 of the famous and non-famous faces were studied for 1 s and 6 for 4 s. Similarly, the recognition phase again consisted of 32 faces in each block. 24 of the faces were from the previous study list and 8 were novel foils (i.e., old/new ratio of 75/25), in which half of the faces from both categories were famous or non-famous. The blocked design in Experiment 2 was identical to that of Experiment 1, except for the use of a fully randomized trial order. During recognition, each face was presented for 2.5 s during which time they were required to make a remember (R), know (K), or new (N) response using the left, down or right computer keys. If the participant indicated the image was from the previous study list (i.e., R or K), they were required to complete one additional memory judgement testing source memory. The source memory judgement required participants to indicate the colour of the rectangular border presented with the face during study from the onscreen options: "Red", "Blue", or "Don't Know". Thought probes were not included in Experiment 2 to simplify the procedure.

After the 8 study-test blocks of task were completed, participants were briefly interviewed for ~5 min regarding their memory strategies. Afterwards, participants were given a surprise delayed recognition memory test. All 256 faces from the previous 8 blocks of the experiment (i.e., both studied targets and novel foils) in addition to 32 entirely novel unstudied faces (16 famous and 16 non-famous) were included in a fully randomized order for the delayed test. Trials were self-paced, and participants responded with the index finger of both hands using the buttons Q or P on the keyboard with response mapping counterbalanced across participants. Each trial began with a 500 ms green fixation cross, followed by the presentation of a face in the centre of the screen. Participants were first required to indicate whether the face was old (i.e., a target or foil previously seen in the experiment) or new (i.e., entirely novel, not seen in the experiment). Next, participants were asked to indicate whether they believed the face was of a famous or non-famous individual, based on their personal experience. For faces judged as famous, participants were then required to indicate how much they knew about the individual on a scale of 1 (very little) to 5 (a lot) using the number pad on the keyboard. Participants then indicated whether or not they could name the famous individual. On average, participants recognized 88% (SD = 10%) of famous faces while failing to recognize 91% (SD = 10%) of the non-famous faces. Accurately recognized famous faces were associated with an average prior knowledge rating of 3.19 (SD = 0.66) across all participants. Famous faces used in this experiment were highly recognizable, again consistent with online norming and Experiment 1. Final analyses were restricted to only include faces that were correctly recognized as either famous or non-famous in the post-test.

Analyses

All statistical analyses were conducted using R (R Core Team 2020). For this experiment and all subsequent experiments, repeated measures ANOVAs were implemented using the *ez* package (Lawrence, 2016) and mixed effect logistic regressions were implemented using *glmer* from the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015). Effect sizes were reported using generalized η^2 or Cohen's d where appropriate.

Results

Analyses from Experiment 1 were replicated in Experiment 2. The results are consistent across both experiments, indicating a reliable benefit of prior knowledge and encoding duration on overall recognition accuracy. Extrinsic context operationalized via Remember hits and objective source memory accuracy, was again better recalled for famous faces. Improved source memory accuracy for famous faces was again largely driven by a boost in source hits. The details of these analyses are reported below.

Prior knowledge improves overall recognition

The effect of prior knowledge and encoding duration on recognition d′ was measured using a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) × 2 (design: mixed, blocked) mixed factorial ANOVA, where design was included as a between-subjects factor (see Fig. 3A). Significant main effects of prior knowledge [$F(1,46) = 88.37$, $p < 0.0001$, $\eta^2_G = .226$] and encoding duration [$F(1,46) = 32.18$, $p < 0.0001$, $\eta^2_G = .009$] were observed. The presence of prior knowledge and a longer encoding opportunity during study both improved subsequent recognition accuracy, but again, prior knowledge produced the larger accuracy benefit. The only other effect to reach significance was an interaction between design and encoding duration [$F(1,46) = 5.30$, $p = 0.03$, $\eta^2_G = .001$], which was driven by a larger benefit of longer encoding durations in the blocked [$t(23) = 6.06$, $p < 0.0001$, *Cohen's* $d = 0.06$] as compared to mixed design [$t(23) = 2.24$, $p = 0.035$, *Cohen's* $d = 0.02$].

Prior knowledge facilitates recognition via Remember hits

Overall recognition was unpacked into Remember and Know response rates for hits and false alarms separately. First, hit rates were examined using a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) × 2 (response type: Remember, Know) × 2 (design: mixed, blocked) mixed factorial ANOVA, where design was included as a between-subjects factor (see Fig. 3B). A three-way interaction between prior knowledge and encoding duration and response type was observed [$F(1,46) = 5.86$, $p = 0.019$, $\eta^2_G = .003$]. Simple effects were conducted by examining Remember and Know hits separately. For Remember hits, a significant interaction was observed between prior knowledge and encoding duration [$F(1,46) = 9.28$, $p = 0.0038$, $\eta^2_G = .005$], driven by a larger benefit of prior knowledge for 1 s [$t(47) = 10.77$, $p < 0.0001$, *Cohen's* $d = 1.03$] as opposed to 4 s encoding [$t(47) = 8.48$, $p < 0.0001$, *Cohen's* $d = 0.86$]. For Know hits, significant main effects of prior knowledge [$F(1,46) = 42.11$, $p < 0.0001$, $\eta^2_G = .169$] and encoding duration were observed [$F(1,46) = 22.69$, $p < 0.0001$, $\eta^2_G = .012$] with no interaction. Unlike Remember hits, Know hits were more frequent for non-famous faces and for 1 s encoding. Note that this opposing pattern is reasonable considering Remember and Know are not independent: more Remember responses implies fewer Know responses.

Finally, false alarm rates were submitted to a 2 (prior knowledge: famous, non-famous) × 2 (response type: Remember, Know) × 2 (design: mixed, blocked) mixed factorial ANOVA (see Fig. 3B). A significant interaction was observed between prior knowledge and response type [$F(1,46) = 18.26$, $p < 0.0001$, $\eta^2_G = .027$], driven by fewer false alarms for famous Know trials [$t(47) = -4.06$, $p = 0.00019$, *Cohen's* $d = -0.34$], with no difference in Remember trials [$t(47) = 0.39$, $p = 0.70$, *Cohen's* $d = 0.04$].

Prior knowledge boosts source memory hits

Next, objective source memory accuracy from all accurately recognized trials were submitted to a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) × 2 (design: mixed, blocked) mixed factorial ANOVA (see Fig. 3D). A significant main effect of prior knowledge [$F(1,46) = 70.02$, $p < 0.0001$, $\eta^2_G = .185$] was observed. Encoding duration had a marginal impact on source memory but was not statistically significant [$F(1,46) = 3.13$, $p = 0.083$, $\eta^2_G = 0.005$]. No other effects were statistically significant ($F < 1$). Although Experiment 2 reveals a marginal improvement in source memory accompanying a longer

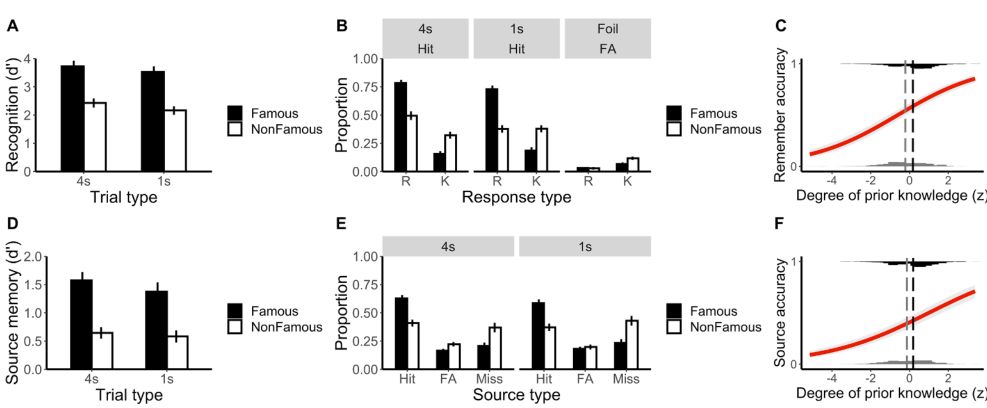

Fig. 3. Results from Experiment 2: Replication of the prior knowledge benefit on overall recognition and memory for extrinsic context. **(A)** Effect of prior knowledge (i.e., famous, non-famous) and encoding duration (1 s, 4 s) on overall recognition accuracy [i.e., d′ = z(hits) – z(false alarms)]. **(B)** Overall recognition unpacked into proportion of hits and false alarms for Remember and Know responses, separately. Better recognition for famous faces is driven by a boost in Remember hits. **(C)** Results of mixed effects logistic regression predicting the likelihood of a Remember hit for famous faces based on degree of prior knowledge. Grey envelope represents 95% confidence intervals estimated around the regression parameter using 500 bootstraps. Black histogram reflects the distribution of prior knowledge ratings for all Remember hit trials. Grey histogram reflects prior knowledge ratings for all other trials. Dashed lines represent the mean of each distribution, respectively. **(D)** Effect of prior knowledge and encoding duration on source memory accuracy [i.e., d′ = z(source hits) – z(source false alarms)]. **(E)** Source memory accuracy unpacked into hits (accurate source), false alarms (source misattribution), and misses (forgotten source). Proportion in the case of source memory is based on the total of trials with correct item recognition only. **(F)** Results of mixed effects model predicting the likelihood of a source memory hit based on degree of prior knowledge. Histograms, medians and confidence intervals were derived identically to Fig. 3C, except using source hits vs. other source trials (i.e., false alarms, misses). Error bars for all bar plots represent standard error of the mean.

study opportunity, prior knowledge again produced the more robust benefit to source memory accuracy, thus replicating Experiment 1.

To unpack overall source accuracy, source memory response rates were submitted to a 2 (prior knowledge: famous, non-famous) × 3 (response type: hit, false alarm, miss) × 2 (design: mixed, blocked) mixed factorial ANOVA (see Fig. 3E). A significant 3-way interaction between prior knowledge and response type and design was observed [$F(2,92) = 5.56$, $p = 0.0053$, $\eta_G^2 = .012$]. To unpack this interaction, mixed and blocked designs were analyzed separately. For the mixed design, the interaction between prior knowledge and response type persisted [$F(2,46) = 50.70$, $p < 0.0001$, $\eta_G^2 = .199$]. Prior knowledge was associated with more source hits [$t(23) = 9.38$, $p < 0.0001$, *Cohen's* $d = 0.48$], no effect on source false alarms [$t(23) = -0.30$, $p = 0.76$, *Cohen's* $d = -0.04$], and a reduction in source misses [$t(23) = -6.91$, $p < 0.0001$, *Cohen's* $d = -0.39$]. For the blocked design, a significant interaction between prior knowledge and response type was again observed [$F(2,46) = 24.19$, $p < 0.0001$, $\eta_G^2 = .095$]. Prior knowledge was again associated with more source hits [$t(23) = 6{,}18$, $p < 0.0001$, *Cohen's* $d = 0.48$], a significant reduction in source false alarms [$t(23) = -2.83$, $p = 0.009$, *Cohen's* $d = -0.37$], and a reduction in source misses [$t(23) = -4.41$, $p = 0.0002$, *Cohen's* $d = -0.16$].

A graded effect of prior knowledge on memory for extrinsic context

The presence of prior knowledge at encoding was associated with better memory for extrinsic context from the study episode, both in terms of the Remember hits and source memory accuracy. If prior knowledge indeed affords more available attentional resources at encoding, then it would follow that the *degree* of prior knowledge associated with a specific stimulus should predict memory for extrinsic context from the study episode. To this end, we conducted a multilevel logistic regression model to test whether a dichotomous measures of extra-item detail per studied trial, defined separately using Remember or source memory accuracy, could be predicted by the degree of prior knowledge reported for a given famous face (see Fig. 3C, F). When using Remember responses, a studied trial was considered accurate only if it received a Remember response. All other studied trials received a 0. When using source memory, a studied trial was accurate only if a participant correctly recalled the border colour from study. All other studied trials received a 0. Degree of prior knowledge associated with a given stimulus was operationalized as its subjective 1 (low) – 5 (high) rating of fame, and z-scored within participant. Only famous face trials that were accurately recognized, both at immediate test and in the post-test fame judgement, were entered into this model, thus isolating degree of prior knowledge. Subject and face stimulus were treated as random effects. Ninety-five percent confidence intervals were then generated around our model estimates via a bootstrapping procedure (sampling with replacement, 500 repetitions).

For Remember accuracy, a Wald test demonstrated that degree of prior knowledge was indeed predictive of Remember accuracy ($X^2(1) = 214.83$, $\beta = 0.44$, β 95% CI = [0.39, 0.50], $p < .0001$). This positive relationship between prior knowledge and Remember hits extended to objective source memory accuracy ($X^2(1) = 145.68$, $\beta = 0.38$, β 95% CI = [0.32, 0.44], $p < .0001$), further confirming a positive relationship between the availability of prior knowledge and memory for extrinsic context.

Prior knowledge facilitates the intentional and incidental formation of durable memories

To characterize any lasting effects of prior knowledge on recognition memory, we analyzed performance on a surprise delayed recognition memory test presented after the completion of the 8 study-test blocks. First, delayed recognition for intentionally studied targets was examined. Delayed recognition accuracy was defined as d′. Only trials that were accurately recognized at immediate recognition contributed to delayed recognition memory analyses. This ensured that any bias from immediate recognition would not persist into the delayed recognition results. The lasting effects of prior knowledge and encoding duration on delayed recognition accuracy were measured using a 2 (prior knowledge: famous, non-famous) × 2 (encoding duration: 1 s, 4 s) × 2 (design: mixed, blocked) mixed factorial ANOVA (see Fig. 4). A significant main effect of prior knowledge [$F(1,46) = 104.43$, $p < 0.0001$, $\eta_G^2 = .276$] was observed, as famous faces were better recognized in the surprise delayed test. A marginal effect of encoding duration was observed [$F(1,46) = 3.31$, $p = 0.08$, $\eta_G^2 = .001$], however no other effects were significant (all $Fs < 1.3$). Overall, these data demonstrate that prior knowledge benefitted the formation of durable memories over and beyond any effect of encoding duration.

As all correctly recognized targets and foils from immediate recognition were defined as targets during the delayed recognition memory test, we were able to additionally test delayed recognition for both accurately recognized targets and correctly rejected foils from immediate recognition. Foils from immediate recognition were not explicitly studied, and thus delayed recognition of these faces provides a measure of the effect of prior knowledge on incidental encoding. Note that a given face stimulus may have been an intentionally encoded target for one participant or an incidentally encoded foil for another, thus making it unlikely that stimulus selection effects can explain any potential differences of encoding type. Also, encoding duration was not included in this model as the incidentally encoded faces were not presented during the study period. The effects of prior knowledge and encoding type on delayed recognition accuracy were measured using a 2 (prior knowledge: famous, non-famous) × 2 (encoding type: intentional, incidental) × 2 (design: mixed, blocked) mixed factorial ANOVA. Significant main effects of prior knowledge [$F(1,46) = 95.30$, $p < 0.0001$, $\eta_G^2 = .318$] and encoding type [$F(1,46) = 230.19$, $p < 0.0001$, $\eta_G^2 = .150$] were observed. As expected, intentional encoding benefitted delayed recognition memory accuracy as compared to incidental encoding (see Fig. 4). Interestingly, prior knowledge enhanced delayed recognition for both intentional and incidental encoding conditions, highlighting the benefit of prior knowledge on the formation of durable memories even in the absence of explicit encoding instructions.

Interim summary

Experiment 2 replicated and extended the results of Experiment 1, demonstrating that a participant's degree of prior knowledge for a given stimulus was indeed predictive of memory for extrinsic context, operationalized as Remember hits and source memory accuracy. This graded relationship between prior knowledge and memory detail is consistent with resource-based models, as the amount of attentional resources expended on encoding should be directly related to how easily a given stimulus can be parsed into a meaningful chunk (e.g., Popov & Reder,

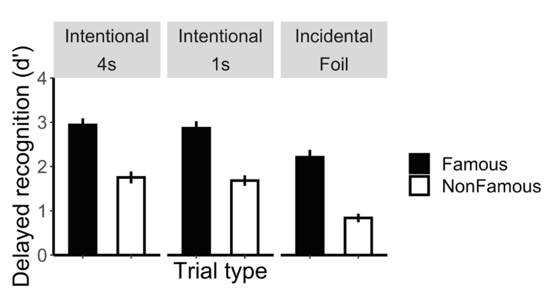

Fig. 4. Delayed recognition from Experiment 2: Prior knowledge benefited recognition accuracy for a surprise delayed recognition test for all 256 faces from the experiment. Famous faces were better remembered whether they were studied targets (Intentional) or correctly rejected foils during the immediate test, highlighting the efficiency of the process when prior knowledge is available. Longer encoding duration failed to produce a comparable benefit.

2020). In Experiment 2, longer encoding duration was also associated with an increase in both Remember and source hits, although to a lesser extent than prior knowledge, again emphasizing the importance of semantic associations during encoding.

Furthermore, performance on a surprise delayed recognition memory test was greater for faces with prior knowledge, while encoding duration had no discernable impact. The benefit of prior knowledge on delayed recognition was observed for intentionally (viz., studied targets from immediate test) and incidentally studied faces alike (viz., correctly rejected foils from immediate test), consistent with the idea that stimuli associated with prior knowledge are more easily encoded. Similar results have been reported using depth of processing manipulations with word stimuli, such that participants performed better on a surprise recognition test when they were oriented towards a words semantic meaning during study (e.g., does this word fit in this sentence?) as compared to its surface level features (e.g., is this word printed in capital letters?) (Craik & Tulving, 1975). Again, the lack of benefit of encoding duration on delayed recognition highlights the importance attending to semantic associations, above extended exposure alone, on the formation of lasting memories.

In addition to the overall replication, we observed subtle differences in the extent to which prior knowledge affected memory for extrinsic context depending on whether the study and test contained both famous and non-famous (mixed) or either famous or non-famous faces (blocked). Famous faces were associated with fewer source false alarms and less source forgetting in the blocked as compared to the mixed design, indicating that the benefit of prior knowledge on memory for extra-item detail is better in blocked as compared to mixed designs. This interpretation is consistent with resource-based accounts, as unfamiliar stimuli may benefit from the attentional resources made available from the efficient encoding of neighbouring familiar stimuli (for related discussion, see Popov & Reder, 2020).

In Experiment 1 and 2, we used famous faces to demonstrate a clear and robust effect of prior knowledge on memory for extrinsic context. Though famous faces are an effective way to evoke prior knowledge, we cannot exclude the possibility that the effects reported above may be restricted to face stimuli. To examine this possibility, we ran an additional experiment in which the memoranda were replaced with images of common and uncommon brands of food and beverages.

Experiment 3

In Experiment 3, we replicate our previous design using common and uncommon brands of foods and beverages instead of famous and non-famous faces. Akin to famous faces, some foods and beverages are highly prevalent in a North American context, and thus should be associated with more prior knowledge in North American participants as compared to their unfamiliar, international counterparts. Broadly, we hypothesized that prior knowledge may operate in a domain general manner, predicting memory for extrinsic context similarly for food items as we previously demonstrated with faces. We also expect the benefit of prior knowledge on extrinsic context to exceed any benefit of encoding duration. It is important to note that our food and beverage stimuli were necessarily more heterogeneous than faces as they were drawn from numerous identifiable categories (e.g., chocolate bars, chips, candies, carbonated beverages, etc.). As such, participants could make use of such category-level information to support the recognition of uncommon stimuli which would be less salient for non-famous faces. Therefore, we expected less of a benefit of prior knowledge on overall recognition as compared to Experiments 1 and 2.

Methods

Participants

Fifty-five young adults between 19 and 30 years of age participated in the experiment. Participants were recruited from the University of Toronto and surrounding areas and were compensated $10/hour. An average testing session lasted 2 h. Seven participants did not meet our inclusion criteria for the final sample and were excluded from subsequent analyses [i.e., did not recognize at least 70% of common or correctly reject at least 70% of uncommon food and beverage stimuli (n = 5), or issues with the experiment software (n = 2)]. Our final sample consisted of 48 participants (years of age: $M = 22.3$, $SD = 3.5$; years of education: $M = 15.4$, $SD = 2.0$; $n_{female} = 35$), identical to that used in Experiment 2.

Stimuli

Images were obtained from the Internet using Google image search, amounting to a total pool of 400 images. Two-hundred images were of common North American foods/beverages and 200 were of uncommon international foods/beverages. All images were selected to have prominent and recognizable logos, while ensuring all lettering was restricted to alphabets based in Latin script. Both common and uncommon pools were matched for the number of stimuli of a specific type (e.g., chocolate bars, chips, candies, carbonated beverages, etc.) to ensure they had comparable compositions. The images had their backgrounds removed and were manually centered and resized to fit within a 475x595 pixel frame. Unlike faces, images remained in original colour to facilitate their identification and association with prior experience. An in-lab pilot study was conducted to collect normative subjective ratings on our stimuli. Nine raters were presented with a list of all brand names for the 400 food and beverage stimuli and were asked to provide a rating on a 3-point scale regarding their personal familiarity with each item. The scale ranged from 0 (no knowledge of this item) to 2 (considerable knowledge of this item). No images were provided, and ratings were provided based entirely on brand names only. Stimuli were then manually selected to create two stimulus pools that were either highly familiar (i.e., common) or highly unfamiliar (i.e., uncommon) to our raters, while again ensuring that the two pools were matched in terms of their composition (e.g., chocolate bars, chips, candies, carbonated beverages, etc.).

Two-hundred and fifty-six food and beverage items (128 common, 128 uncommon) formed the final stimulus pool for Experiment 3. Images of 32 additional novel foods and beverages (16 common, 16 uncommon), from the overall 400 item stimulus pool, were included as novel foils in a surprise delayed recognition test, as described in Experiment 2.

Procedure

Participants made Remember-Know judgements on 128 common and 128 uncommon food and beverage items (96 targets, 32 foils each) using an identical procedure to Experiment 2′s mixed design. First, participants performed 8 study-test blocks for the immediate test, followed by a brief interview regarding their memory strategies. Afterwards, participants were given a surprise delayed recognition memory test, as in Experiment 2. All 256 images from the previous 8 blocks of the experiment (i.e., both studied targets and novel foils) in addition to 32 entirely novel unstudied foils (16 common and 16 uncommon) were included in a fully randomized order for the delayed test. The surprise delayed recognition test followed an identical procedure to Experiment 2, including an additional question asking participants how much they would want to consume the food or beverage on a 5-point scale.

On average, participants recognized 91% (SD = 6%) of common foods and beverages, while failing to recognize 91% (SD = 6%) of the uncommon foods and beverages. Common food and beverages were associated with an average prior knowledge rating of 3.47 (SD = 0.64) across all participants. Overall, these data suggest that the common stimuli used in this experiment reliably evoked prior knowledge in our participants. Final analyses were restricted to only include stimuli that were correctly recognized as either common or uncommon in the post-test. It is possible that participants recognized uncommon food and beverages, but excluding these trials more closely followed the procedures from the previous experiments.

Results

Prior knowledge does not improve overall recognition

The effect of prior knowledge and encoding duration on recognition d′ was measured using a 2 (prior knowledge: common, uncommon) × 2 (encoding duration: 1 s, 4 s) repeated measures ANOVA (see Fig. 5A). A significant main effect of encoding duration was observed [$F(1,47) = 59.87$, $p < 0.0001$, $\eta^2_G = .02$], as longer exposure during study was associated with better memory. The main effect of prior knowledge was not statistically significant [$F(1,47) = 0.14$, $p = 0.71$, $\eta^2_G = .001$]. An interaction between prior knowledge and encoding duration [$F(1,47) = 7.47$, $p = 0.009$, $\eta^2_G = .002$] was also observed, driven by a larger benefit of encoding duration on recognition for uncommon [$t(47) = 7.54$, $p < 0.0001$, *Cohen's* $d = 0.34$] as compared to common foods and beverages [$t(47) = 3.71$, $p = 0.0005$, *Cohen's* $d = 0.20$].

Prior knowledge leads to more Remember hits

Although prior knowledge did not boost overall recognition with food and beverages, it remains possible that it can differentially support Remember as opposed to Know responses, providing subjective evidence for more detailed memory. To this end, Remember and Know response rates were analyzed separately for hits and false alarms. First, hit rates were examined using a 2 (prior knowledge: common, uncommon) × 2 (encoding duration: 1 s, 4 s) × 2 (response type: Remember, Know) repeated measures ANOVA (see Fig. 5B). Significant interactions between prior knowledge and encoding duration [$F(1,47) = 8.11$, $p = 0.007$, $\eta^2_G = .001$], prior knowledge and response type [$F(1,47) = 82.00$, $p < 0.0001$, $\eta^2_G = .34$], and encoding duration and response type [$F(1,47) = 20.76$, $p < 0.0001$, $\eta^2_G = .016$] were observed. To examine the relationship between prior knowledge and memory detail, we first unpacked the interaction between prior knowledge and response type. Paired t-tests revealed that, indeed, common foods and beverages were associated with a steep increase in Remember hits [$t(47) = 9.37$, $p < .0001$, *Cohen's* $d = 1.20$] and a comparably sharp drop in Know hits [$t(47) = -8.46$, $p < 0.0001$, *Cohen's* $d = -1.15$]. Next, the interaction between prior knowledge and encoding duration was driven by a larger benefit of longer study for uncommon [$t(47) = 6.97$, $p < .0001$, *Cohen's* $d = 0.35$] as compared to common foods and beverages [$t(47) = 3.85$, $p = .0004$, *Cohen's* $d = 0.19$]. Finally, the interaction between encoding duration and response type revealed that encoding duration also benefitted Remember [$t(47) = 7.21$, $p < .0001$, *Cohen's* $d = .14$] as opposed to Know hits [$t(47) = -1.65$, $p = 0.10$, *Cohen's* $d = -0.05$].

False alarm rates were also submitted to a 2 (prior knowledge: famous, non-famous) × 2 (response type: Remember, Know) repeated measures ANOVA (see Fig. 5B). A main effect of response type reached significance [$F(1,47) = 12.2$, $p = 0.001$, $\eta^2_G = .055$], driven by fewer Remember false alarms as compared to Know. No effects involving prior knowledge reached significance [$F =< 1$].

Prior knowledge boosts source memory hits

Next, objective source memory accuracy from all accurately recognized trials were submitted to a 2 (prior knowledge: common, uncommon) × 2 (encoding duration: 1 s, 4 s) repeated measures ANOVA (see Fig. 5D). A main effect of prior knowledge was significant [$F(1,47) = 18.38$, $p < 0.0001$, $\eta^2_G = .053$], as common foods and beverages were associated with better source memory accuracy than their uncommon counterparts. A marginal effect of encoding duration was also observed [$F(1,47) = 3.08$, $p = 0.086$, $\eta^2_G = .004$], providing some evidence that longer encoding durations may have benefitted objective source memory.

To unpack the effect of prior knowledge on source memory accuracy, source memory response rates were submitted to a 2 (prior knowledge: famous, non-famous) × 3 (response type: hit, false alarm, miss) repeated measures ANOVA (see Fig. 5E). A significant interaction between prior knowledge and response type was observed [$F(2,94) = 33.51$, $p < 0.0001$, $\eta^2_G = .055$]. Common foods and beverages were associated with more source hits [$t(47) = 6.72$, $p < 0.0001$, *Cohen's* $d = 0.30$], fewer source false alarms [$t(47) = -2.09$, $p = 0.042$, *Cohen's* $d = -0.06$], and a fewer source misses [$t(47) = -5.65$, $p < 0.0001$, *Cohen's* $d = -0.15$].

A graded effect of prior knowledge on memory for extrinsic context

The relation between degree of prior knowledge and estimates of extrinsic context (i.e., Remember and source memory) were tested using an identical multilevel logistic regression procedure as employed in

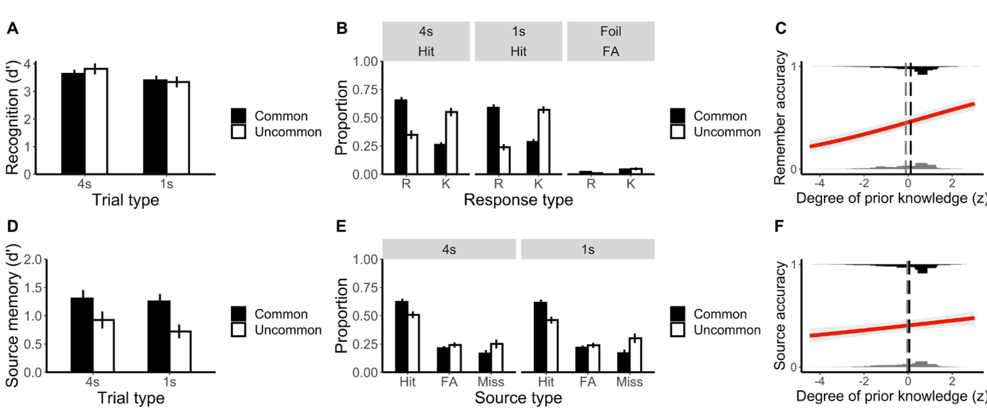

Fig. 5. Results from Experiment 3: General replication of the prior knowledge benefit on overall recognition and memory for extrinsic context using food and beverage stimuli. **(A)** Effect of prior knowledge (i.e., common, uncommon) and encoding duration (1 s, 4 s) on overall recognition accuracy [i.e., d′ = z (hits) – z(false alarms)]. **(B)** Overall recognition unpacked into proportion of hits and false alarms for Remember and Know responses, separately. Note that common food items were associated with a boost in Remember hits. **(C)** Results of mixed effects logistic regression predicting the likelihood of a Remember hit for common food/beverages based on degree of prior knowledge. Grey envelope represents 95% confidence intervals estimated around the regression parameter using 500 bootstraps. Black histogram reflects the distribution of prior knowledge ratings for all Remember hit trials. Grey histogram reflects prior knowledge ratings for all other trials. Dashed lines represent the mean of each distribution, respectively. **(D)** Effect of prior knowledge and encoding duration on source memory accuracy [i.e., d′ = z(source hits) – z(source false alarms)]. **(E)** Source memory accuracy unpacked into hits (accurate source), false alarms (source misattribution), and misses (forgotten source). Proportion in the case of source memory is based on the total of trials with correct item recognition only. **(F)** Results of mixed effects model predicting the likelihood of a source memory hit based on degree of prior knowledge. Histograms, medians and confidence intervals were derived identically to Fig. 5C, except using source hits vs. other source trials (i.e., false alarms, misses). Error bars for all bar plots represent standard error of the mean.

Experiment 2. Logistic regression models are plotted in Fig. 5C and F. Wald tests again revealed that degree of prior knowledge predicted Remember responses ($X^2(1) = 71.23$, $\beta = 0.25$, β 95% CI = [0.19, 0.30], $p < .0001$). The relationship between prior knowledge and objective source memory accuracy was also statistically significant, though weak ($X^2(1) = 11.97$, $\beta = 0.10$, β 95% CI = [0.04, 0.15], $p = .0005$). Overall, these results extend the positive relation between degree of prior knowledge and memory for extrinsic context beyond face stimuli.

Prior knowledge facilitates the incidental formation of durable memories

To test the lasting effects of prior knowledge on recognition memory, we analyzed performance on a surprise delayed recognition memory test presented after the completion of the 8 study-test blocks. The lasting effects of prior knowledge and encoding duration on delayed recognition accuracy (d′) of intentionally studied targets were measured using a 2 (prior knowledge: common, uncommon) × 2 (encoding duration: 1 s, 4 s) repeated-measures ANOVA (see Fig. 6). A significant main effect of encoding duration was observed [$F(1,47) = 4.20$, $p = 0.046$, $\eta^2_G = .002$]. Interestingly, the main effect prior knowledge [$F(1,47) = 1.05$, $p = 0.31$, $\eta^2_G = .004$] and the interaction between with prior knowledge and encoding duration [$F(1,47) = 1.86$, $p = 0.18$, $\eta^2_G = .001$] were not statistically significant.

Lastly, we examined whether we could replicate the benefit of prior knowledge on the *incidental* formation of durable memories. Therefore, the effects of prior knowledge and encoding type on delayed recognition accuracy (d′) were measured using a 2 (prior knowledge: common, uncommon) × 2 (encoding type: intentional, incidental) repeated-measures ANOVA (see Fig. 6). A significant interaction between prior knowledge × encoding type was observed [$F(1,47) = 33.07$, $p < 0.0001$, $\eta^2_G = .013$]. Tests of simple effects were conducted using pairwise t-tests comparing the effect of prior knowledge on delayed recognition for intentional and incidental targets separately. As reported above, the benefit of prior knowledge on delayed recognition accuracy was not statistically significant for intentional encoding [$t(47) = 1.03$, $p = 0.31$, *Cohen's* $d = 0.08$], whereas this effect was robust for incidental encoding [$t(47) = 4.32$, $p < 0.001$, *Cohen's* $d = 0.51$]. This finding partially replicates our previous results with faces, in which prior knowledge facilitated the incidental formation of durable memories.

Interim summary

Experiment 3 generally replicated the results of Experiments 1 and 2 using food and beverage stimuli. Common images were associated with a shift towards Remember hits and improved source memory accuracy, providing strong evidence for a domain-general benefit of prior knowledge on memory for extrinsic context, consistent with resource-based accounts. Prior knowledge also benefitted delayed recognition

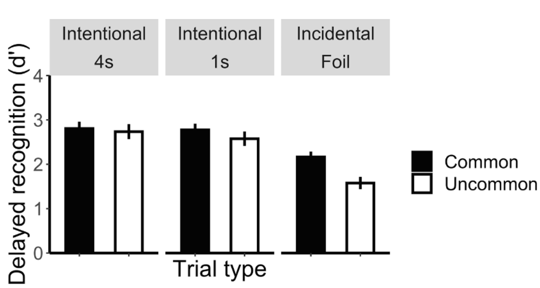

Fig. 6. Delayed recognition from Experiment 3: Prior knowledge benefited recognition accuracy for a surprise delayed recognition test for all 256 food and beverage images from the experiment. Common food and beverages were better remembered when they were studied incidentally as correctly rejected foils during the immediate test (Incidental), highlighting the efficiency of the process when prior knowledge is available. Longer encoding duration failed to produce a comparable benefit on delayed recognition.

under incidental encoding. We did not observe a benefit of prior knowledge on overall recognition or delayed recognition under intentional encoding. One plausible explanation for this discrepancy is the heterogeneity associated with food and beverages as compared to faces. The food and beverage stimuli used in this experiment were highly discriminable at the category-level (e.g., type of food/beverage) and associated visual features (e.g., shape, colour). Furthermore, all stimuli were clearly branded, and verbal labels are known to be powerful determinants of memory performance for novel stimuli (Lupyan, Rakison, & McClelland, 2007; Schwartz & Yovel, 2016). Unlike with unfamiliar faces, that are an especially homogeneous stimulus class, participants could make use of the distinctive attributes of uncommon food and beverages to support memory performance even in the absence of prior knowledge. Another difference between food and beverage stimuli as compared to faces is that they were more likely to elicit accurate Know responses as compared to faces, where correct recognition tends to be driven by Remember responses (see Figs. 3B and 5B). The precise reasons why this occur remain an open question. One possibility is that the availability of category level information (e.g., chocolate bar, cereal, soda) and visible brand names may have elicited recognition strategies that were not available for faces, which in turn had downstream consequences on the relative frequency of Remember and Know hits.

Across three experiments, we demonstrate that prior knowledge increases the likelihood of recalling extrinsic contextual details from a study episode. These findings are consistent with resource-based accounts of memory (e.g., DeWitt et al., 2012; Diana & Reder, 2006; Popov & Reder, 2020; Reder et al., 2013), but inconsistent with schema-based accounts that posit an inverse relationship between the activation of preexisting knowledge and the encoding of episodic details from a study episode (e.g., van Kesteren et al., 2012). Evidence for schema-based generalization, however, may be restricted to memory for the perceptual details that make up the studied target itself. In other words, the process of chunking information in a study episode may be lossy rather than lossless (Sayood, 2003; see also Mathy & Feldman, 2012; Nassar et al., 2018; Norris & Kalm, 2018), leading to a specific loss of precision for the chunked information itself, while simultaneously freeing resources for the encoding of extrinsic context. Alternatively, a pure resource-based account would predict a general boost in memory detail for familiar stimuli, given they require fewer resources to encode, leaving more attentional resources to available to encode intrinsic and extrinsic context alike. We examine these possibilities in Experiment 4.

Experiment 4

To adjudicate between a resource-based and schema-based account of how prior knowledge should influence memory for intrinsic context, we conducted a final experiment based on the mnemonic similarity task (MST) (Kirwan & Stark, 2007; Stark et al., 2013). In the MST, accurate recognition requires the correct rejection of highly perceptually similar lures. Therefore, if the benefit of prior knowledge extends to the precise, perceptual details that make up the studied target itself, then participants should be able to use these representations to accurately discriminate between studied targets and highly similar lures.

Methods

Participants

Seventy-five young adults between 19 and 30 years of age participated in the experiment. Participants were recruited from the University of Toronto and surrounding areas and were compensated $10/hour. An average testing session lasted 2 h. Fifteen participants did not meet our inclusion criteria for the final sample and were excluded from subsequent analyses [i.e., did not recognize at least 70% of famous or correctly reject at least 70% of non-famous faces (n = 14), or issues with the experiment software (n = 1)]. Our final sample consisted of 60 participants (years of age: $M = 22.5$, $SD = 3.3$; years of education: $M = 15.8$, $SD = 2.4$; $n_{female} = 45$), and was comparable in size to previous publications using this paradigm (e.g., Stark et al., 2013).

Stimuli

Identical face images from Experiment 1 and 2 were used in Experiment 4. Unlike the previous experiments, each image was flipped horizontally to produce mirror images of the original stimuli. Therefore, by capitalizing on the slight variations between original and flipped images, we were able to test whether the observed benefits of prior knowledge on recollection would also extend to more fine-grained perceptual discriminations during recognition (i.e., recognition of face identity *and* orientation), while holding the low-level visual properties of the stimuli constant. To confirm that faces were comparably symmetrical, we correlated the pixel intensities of the two image halves. Pearson correlations were then compared using an independent samples *t*-test, confirming that famous and non-famous faces comparably symmetrical ($M_{famous} = 0.87$, $M_{non\text{-}famous} = 0.85$; $t(254) = 1.47$, $p = 0.14$). One remaining concern with this paradigm is the possibility that famous faces are more likely to be recognized as flipped during encoding, which could then lead to a difference in encoding strategies. However, a control experiment on a separate group of participants indicated that they could not reliably detect which of the two images was the original or flipped, for famous and non-famous faces alike (see Supplementary Material: Section 5).

Procedure

In Experiment 4, we used a procedure based on the MST (Kirwan & Stark, 2007; Stark et al., 2013). This paradigm incorporates similar lures into the standard recognition memory paradigm of targets and foils, thus affording a test of more precise stimulus representations in memory. The details of our paradigm were largely consistent with our previous experiments, with some important distinctions. I) As we were primarily interested in prior knowledge, we held encoding duration constant at 3 s. II) In place of manipulating encoding duration, we manipulated whether or not a studied face was presented in the same orientation across encoding and retrieval (i.e., old) or flipped (i.e., similar), within participants. Therefore, just like the manipulation of encoding duration in Experiments 1–3, half of the studied faces were old trials and half were similar trials, and this was true for both famous and non-famous faces. Also, half of the old and similar trials were initially encoded in the original orientation and half in the flipped orientation to further ensure pre-experimental familiarity with a face would not affect the likelihood of noticing a change in orientation. III) During test, participants were required to decide whether the target face was presented in the same orientation as at encoding (i.e., old), presented in a flipped orientation as compared to encoding (i.e., similar), or was not studied at all (i.e., new). If participants responded either old or similar, an additional prompt appeared asking them to categorize the subjective experience of recognition using Remember and Know, in line with our previous experiments.

After 8 study-test blocks of task were completed, participants were briefly interviewed for ~5 min regarding their memory strategies. Like Experiments 2 and 3, participants then underwent the surprise delayed recognition memory procedure. All 256 face pairs from the previous 8 blocks of the experiment (i.e., both studied targets and novel foils) in addition to 32 entirely novel unstudied pairs (16 famous and 16 non-famous) were included in a fully randomized order. For each trial, the original and flipped versions of a face were presented on either the left or right side of the screen, with position randomly shuffled per trial. In addition to measuring delayed recognition memory and degree of prior knowledge for each face (see Procedure for Experiments 2 and 3), the surprise delayed recognition memory task for Experiment 4 also elicited a rating of how perceptually different the faces in pair appeared to each subject, on a scale of 1 (very little) to 5 (a lot). On average, participants recognized 87% (SD = 12%) of famous faces, while failing to recognize 89% (SD = 8%) of the non-famous faces. Famous faces were associated with an average prior knowledge rating of 3.39 (SD = 1.33) across all participants. Overall, these data suggest that the famous faces used in this experiment reliably evoked prior knowledge in our participants.

Note: except for objective source memory, which was not collected, all results from Experiment 2 were replicated in Experiment 4 (for details, see Supplementary Material: Section 6).

Results

A prior knowledge-dependent bias towards failing to detect changes in intrinsic context

We were interested in examining the effect of prior knowledge on memory for intrinsic context and not simple discrimination between targets and foils. Therefore, recognition was defined as the degree to which participants could accurately recall the studied orientation of a given face, over and above its identity. For old trials, d′ was calculated as the standardized likelihood of responding old to and old trial, minus the likelihood of responding old to a similar trial (i.e., z(old hit) – z(old false alarm)). For similar trials, d′ was calculated as the standardized likelihood of responding similar to a similar trial, minus the likelihood of responding similar to an old trial (i.e., z(similar hit) – z(similar false alarm)).

The effect of prior knowledge and trial type on recognition accuracy was measured using a 2 (prior knowledge: famous, non-famous) × 2 (response type: old, similar) repeated measures ANOVA (see Fig. 7A). A significant main effect of prior knowledge was observed [$F(1,59) = 16.68$, $p = 0.0001$, $\eta_G^2 = .041$], indicating that the overall likelihood of recalling the studied orientation of a given face, beyond recognizing its identity, was higher for famous as compared to non-famous faces. The interaction between prior knowledge and trial type was also statistically significant [$F(1,59) = 6.71$, $p = 0.003$, $\eta_G^2 = .003$], driven by a larger benefit of prior knowledge for similar trials [$t(59) = 4.63$, $p < 0.0001$, *Cohen's* $d = 0.49$] as compared to old trials [$t(59) = 2.84$, $p = 0.006$, *Cohen's* $d = 0.32$].

The above results suggest that overall discriminability is better for famous as compared to non-famous faces. For a more nuanced examination of memory performance, we further unpacked recognition into hits, false alarms and misses. Hits refer to studied trials in which studied orientation is correctly recognized; false alarms refer to studied trials in which a participant endorses the incorrect orientation; misses refer to studied trials that a participant endorses as new. Response rates were submitted to a 2 (prior knowledge: famous, non-famous) × 2 (trial type: old, similar) × 3 (response type: hits, false alarm, miss) repeated measures ANOVA (see Fig. 7B). A significant 3-way interaction was observed [$F(2,118) = 48.31$, $p < 0.0001$, $\eta_G^2 = .084$]. Simple effects were conducted by examining old and similar trials separately. For old trials, the interaction between prior knowledge and response type was significant [$F(2,118) = 61.97$, $p < 0.0001$, $\eta_G^2 = .191$]. Famous faces were associated with the standard pattern of better memory for old trials: more hits [$t(59) = 9.96$, $p < 0.0001$, *Cohen's* $d = 0.82$], fewer false alarms [$t(59) = -4.09$, $p = 0.0001$, *Cohen's* $d = -0.45$], and fewer misses [$t(59) = -7.80$, $p < 0.0001$, *Cohen's* $d = -0.47$].

Interestingly, a different pattern emerged for similar trials. For similar trials, the interaction between prior knowledge and response type was significant [$F(2,118) = 44.56$, $p < 0.0001$, $\eta_G^2 = .145$], but famous faces showed no benefit for hits [$t(59) = -0.54$, $p = 0.59$, *Cohen's* $d = -0.04$], a sizeable increase in false alarms [$t(59) = 7.83$, $p < 0.0001$, *Cohen's* $d = 0.90$], and fewer misses [$t(59) = -9.31$, $p < 0.0001$, *Cohen's* $d = -0.50$].

The observed increase in false alarms on similar trials is consistent with a prior knowledge-dependent shift in the response criterion participants use: irrespective of a face's actual studied orientation, prior

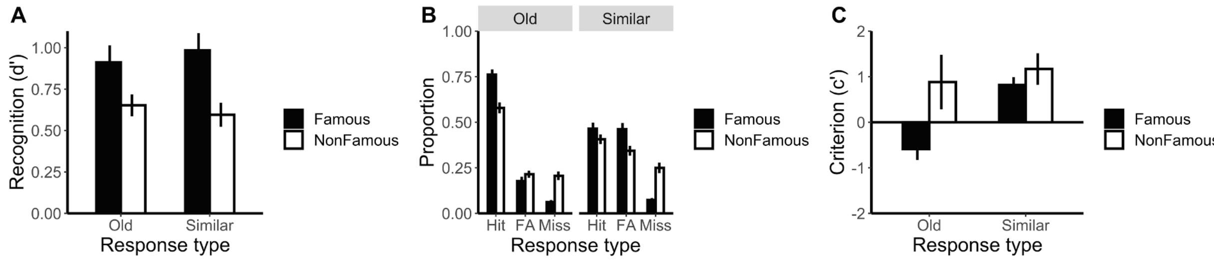

Fig. 7. Results from Experiment 4: Prior knowledge is associated with a loss of intrinsic context in memory. Recognition in this experiment was based on the mnemonic similarity task (MST), in which faces could either be presented in the same orientation from study to test (Old) or horizontally flipped from study to test (Similar). Recognition was defined as the likelihood of correctly endorsing identical faces as old (same orientation from study to test) [i.e., d′ = z(hits for old trials) – z (false alarms for similar trials)] or correctly endorsing a flipped face as similar (different orientation from study to test) [i.e., d′ = z(hits for similar trials) – z(false alarms to old trials)]. **(A)** Effect of prior knowledge (i.e., famous, non-famous) and encoding duration (1 s, 4 s) on recognition accuracy in the MST, revealing an overall accuracy benefit. **(B)** Recognition accuracy unpacked in this hits (correctly remembering orientation), false alarms (misremembering orientation) and misses (forgetting orientation) for Old and Similar trials separately. Proportion is relative to all trials on which general item recognition was accurate, as opposed to all studied trials. In addition to an increase in old hits, prior knowledge was also associated with an increase in falsely endorsing similar faces as old. **(C)** Effect of prior knowledge on relative response criterion [i.e., c′ = –1/2 [z(hits) + z(false alarms)]/d′]. Prior knowledge was associated with a shift towards a more liberal response criterion for making old responses. (i.e., unchanged from study to test). Error bars represent standard error of the mean.

knowledge was associated with an overall increased likelihood of classifying a face as old, or unchanged from study. To better quantify this apparent response bias, we calculated the relative response criterion (*c'*). *c'* is defined as the criterion *c* (where $c = -1/2$ [z(hits) + z(false alarms)]) divided by discriminability d′ (where $d' =$ z(hits) – z(false alarms)) (Macmillan & Creelman, 1990). A *c'* of 0 would indicate unbiased signal detection, while a positive value would indicate a bias towards failing to detect the signal irrespective of its presence (i.e., a conservative response criterion), and a negative value would indicate a bias towards detecting the signal irrespective of its presence (i.e., a liberal response criterion). c' was calculated separately for famous and non-famous faces, and for old and similar responses.

The effect of prior knowledge and response type on *c'* was measured using a 2 (prior knowledge: famous, non-famous) × 2 (response type: old, similar) repeated measures ANOVA. Critically, we observed a significant interaction between prior knowledge and response type [$F(1,59) = 5.10$, $p = 0.03$, $\eta^2_G = .01$] (see Fig. 7C). As expected, paired t-tests indicated that famous faces were indeed associated with a significantly lower *c'* (i.e., more liberal response criterion) than non-famous faces specifically when classifying a face as old [$t(59) = -2.80$, $p = 0.007$, *Cohen's d* = −0.47]. Prior knowledge had no such impact on *c'* for similar responses [$t(59) = -0.73$, $p = 0.47$, *Cohen's d* = −0.14]. Therefore, participants were indeed more likely to endorse a famous face as old (i.e., presented in the same orientation as study) irrespective of its actual studied orientation. This shift in response criterion resulted in a higher likelihood of failing to detect a change in intrinsic context when present, particularly when prior knowledge was available. Furthermore, we replicated this increase in false alarms for similar trials in a separate sample of younger adults (see Supplementary Material: Section 7).

Interim summary

Famous faces were associated with better overall discriminability in the MST paradigm, but examining hit and false alarm rates separately revealed a general bias towards endorsing famous faces as old (i.e., same orientation as study). This led to a high hit rate for famous trials that were presented in the same orientation as study, but also sizeable false alarm rates when the face orientation was flipped. These data provide initial evidence that famous faces may be better remembered overall, however this benefit may come at the cost of memory for fine-grained intrinsic details.

General discussion

Across a series of four experiments, we provide evidence for a robust benefit of prior knowledge on our ability to remember the extrinsic context from a study episode. For face and food stimuli alike, prior knowledge facilitated accurate Remember responses and objective source memory accuracy. Participants' self-reported degree of prior knowledge for a given stimulus predicted its likelihood of being recalled with additional contextual details from the study episode. Despite quadrupling the length of study, encoding duration did not benefit memory for extrinsic context to the same extent. Critically, prior knowledge did not benefit memory for intrinsic context. Although famous faces were associated with better recognition, participants were less likely to notice when their orientation was reversed between study and test as compared to non-famous faces. This finding points to a loss of memory for intrinsic context when prior knowledge is available, despite a facilitatory effect on the encoding of extrinsic context. Overall, these data provide important insight into how a combination of resource and schema-based accounts provides a better explanation for the data on memory detail than either model alone.

Prior knowledge and memory detail

A benefit of prior knowledge on memory for extrinsic context is consistent with previous studies on associative memory and source memory (Brandt et al., 2005; DeWitt et al., 2012; Horry et al., 2010; Liu et al., 2016; Long et al., 2008; Long & Prat, 2002; Poppenk et al., 2010; Reder et al., 2013), and further corroborate the few studies that report a positive relationship between source memory and degree of prior knowledge (DeWitt et al., 2012; Long et al., 2008). These results are also consistent with the effect of deep processing on recollection. Attending to the semantic meaning associated with a stimulus is more likely to produce recollection than attending to its surface-level perceptual features (Bower & Karlin, 1974; Craik, 2002; Craik & Lockhart, 1972; Yonelinas, 2002). One possible explanation for these results may be that attending to semantic meaning facilitates the parsing of incoming experience into memorable chunks. For example, Mathy and Feldman (2012) report better memory for sequences of digits that contained runs of increasing or decreasing values as compared to more erratic sequences. They argued that this finding supports a chunking account, in which any available structure in an input stream can be compressed, which leads to better encoding. Similar findings have been reported in studies in which participants are experimentally familiarized with novel memoranda. In Reder et al. (2016), participants were exposed to previously unfamiliar Chinese characters over the course of a month and measures of associative memory increased as participants became more familiar with the characters, despite the associations themselves being novel. Therefore, stimuli whose semantic associations are accessible, via pre-experimental familiarity or an experimental manipulation like deep processing or when a stimulus gains significance over multiple exposures, may be encoded more efficiently into memory than unfamiliar stimuli. In line with this account, DeWitt et al. (2012) demonstrate that the benefit of prior knowledge on source memory is lost when attention is divided at encoding, but not at retrieval. These results are inconsistent with schema-based accounts that propose an inverse relationship between the activation of prior knowledge and the encoding of episodic details (e.g., van Kesteren et al., 2012).

However, an exclusively resource-based explanation cannot account for the subtle yet reliable decrease in memory for intrinsic context observed for familiar stimuli. Using the MST paradigm, we demonstrate that famous faces were associated with higher false alarm rates to similar trials (see Fig. 7B). In other words, participants were more likely to consider famous faces to be presented in the same orientation from study to test and consequently failed to notice when a famous face was horizontally flipped. Therefore, the benefit of prior knowledge on memory for extrinsic context may come at the cost of the precision with which the stimulus itself is represented (i.e., intrinsic context). This finding is consistent with the idea that famous faces may evoke a general impression of what the individual looks like, which in turn interferes with the encoding of the particularities of their appearance in a given study episode. Recent work with faces suggests that attending to conceptual information when studying an unfamiliar face improves recognition across different lightings and viewpoints (Schwartz & Yovel, 2019), suggesting attending to conceptual information supports the formation of memory representations that are less tethered to the specific image from study (also see Armann et al., 2016; Schwartz & Yovel, 2016). Another compelling account is that the process of parsing our experience into meaningful chunks may rely on lossy, rather than lossless, compression (Sayood, 2003; see also Nassar et al., 2018; Norris & Kalm, 2018). Our memory is far from a direct recapitulation of our experience, and evidence for information loss in episodic memory can be found in studies of memory errors (Schacter, Guerin, & St Jacques, 2011). In his classic work, Bartlett reported systematic errors in participants' recall of stories, in which unfamiliar terms were forgotten and replaced with more familiar concepts (Bartlett, 1932, see also, Rojahn & Pettigrew, 1992; Stangor & Mcmillan, 1992). Another common example of schema-based memory errors comes from the 'Deese-Roediger-McDermott (DRM) paradigm', in which studying conceptually related words (e.g., bed, night, pillow, tired, etc.) elicits false memory for an unstudied lure (e.g., sleep) (Roediger & McDermott, 1995). These errors, however, are not observed in patients with schema processing deficits associated with ventromedial frontal lesions (Melo, Winocur, & Moscovitch, 1999; Warren, Jones, Duff, & Tranel, 2014).

If our capacity to encode details from a study episode were limitless, we should not observe these kinds of memory distortions. Instead, our memory system systematically exploits our prior knowledge to overcome our limited encoding resources. We rely on our existing long-term memory representations and schema instead of encoding all the features from our surroundings anew. This kind of data compression or knowledge-based inference may be computationally efficient (e.g. Mathy & Feldman, 2012), but it appears to come at the cost of memory for intra-item details. This may be especially the case when using complex stimuli, like images of faces, as opposed to lower dimensional stimuli, like words or digits, which may be more easily compressed without information loss. Broadly, our results provide evidence for a loss of memory detail specific to the item itself when prior knowledge is available, highlighting a potential role of schema-based generalization mechanisms in the context of forming detailed memories.

It is important to note, that the data compression metaphor has limitations in its ability to describe human memory. For example, compression algorithms can perfectly decompress (or, reconstruct) compressed data, recreating the encoded representation exactly every time. In other words, even if information were to be lost during encoding, the retrieval mechanism is perfect. Human memory is constructive process and cannot accomplish this perfect mapping between compressed and decompressed representations (e.g., Schacter, Guerin, & St Jacques, 2011). Therefore, we contend that a data compression framework may be useful for conceptualizing how we chunk *incoming* experience (i.e., encoding). Specifically, it highlights that the specific way in which the chunking process is operationalized will have consequences on the fidelity of the encoded representation.

Another caveat regarding the data compression metaphor is that it implies that intrinsic context is lost during encoding. Alternatively, the intrinsic context may be initially encoded for familiar stimuli only to become inaccessible during later retrieval. Another possibility may be that the intrinsic context is both encoded and retrieved but the strong item memory signal associated with famous faces nonetheless leads to a general shift towards a more liberal response criterion for "old" trials. The present experiment cannot adjudicate between these possible explanations. Nonetheless, our data provide depict a subtle yet reliable impairment in memory performance when assessing the intrinsic context of a studied stimulus, particularly when prior knowledge is available.

Prior knowledge and the incidental formation of durable memories

Prior knowledge also supports the formation of durable memories. Studied famous faces were more likely to be recognized during a surprise delayed recognition test than studied non-famous faces. This finding is in line with previous behavioural work showing better memory for familiar stimuli after a delay (Scapinello & Yarmey, 1970). Also previous studies on expertise have reported expertise-related performance benefits on surprise memory tests for the positions of pieces on a chess board (Goldin, 1979) or cards that make up a hand in a game of bridge (Engle & Bukstel, 1978). Improved delayed recognition is also consistent with neural evidence suggesting that prior knowledge is critical for rapid neocortical learning (McClelland, 2013; Sharon et al., 2011; Tse et al., 2007), acting as a "fast route" to memory consolidation (Antony et al., 2017; Gilboa & Marlatte, 2017). Newly learned information becomes stable through consolidation, a process that occurs gradually over time, allowing newly formed memories represented via the hippocampus to integrate with existing knowledge in the neocortex (Kitamura et al., 2017; Liu et al., 2016; Liu, Grady, & Moscovitch, 2018; McClelland, 2013; McClelland et al., 1995). The gradual aspect is necessary for successful consolidation as existing knowledge structures are prone to interference if integration occurs too quickly, particularly when the new learning is inconsistent with prior knowledge (McClelland, McNaughton, O'Reilly, 1995; McClelland, 2013). Information that is already consistent with prior knowledge actually facilitates learning, allowing for more rapid acquisition of durable memory traces represented in the neocortex. The present data do not allow for adequate time between initial study and delayed test for a complete consolidation-based explanation, but they do highlight robust learning in a highly interference-prone context, which may reflect the early stages of an efficient consolidation process (Dudai, Karni, & Born, 2015, see also Li, Hu, & Yang, 2020).

Furthermore, we observed a benefit of prior knowledge on delayed recognition for both intentional (faces) and incidental (faces and food/beverages) encoding conditions, suggesting that explicit study is not necessary to produce this benefit. Similar effects have been observed with depth of encoding manipulations for both studied targets (Craik & Tulving, 1975; Masson & McDaniel, 1981) and incidentally learned foils (Craik & Lockhart, 1972; Jacoby, Shimizu, Daniels, & Rhodes, 2005). Jacoby et al. (2005) presented participants with two lists of words, one learned deeply (pleasantness judgement) and another learned more shallowly (judge whether each word had the vowel O or U). During test, participants were again presented with two lists, one containing deeply processed targets and novel foils and another containing shallowly processed targets and novel foils. Next, participants performed a final recognition memory test, in which they were presented with the foils from the previous test and entirely novel foils. Recognition performance for the foils from the deeply processed list was superior to that of the shallow-list. The authors propose a 'source constrained retrieval' account, such that the deep processing engaged during encoding was reinstated during test, allowing for deeper encoding of the foils. Such an account would not apply to the present experiment, as our novel foils could elicit deeper processing themselves by virtue of their familiarity. However, in both our data and those of Jacoby et al., attending to the semantic associations available for a given stimulus resulted in better incidental encoding of novel foils. Considering that deep processing demands attention (Craik, Eftekhari, & Binns, 2018), processing is necessarily shallower when fewer attentional resources are available, irrespective of whether the encoding is intentional or incidental. Therefore, if the old-new judgement required less attentional resources for famous faces, as would be predicted by a resource-based account, then more resources would be available to encode the stimulus foils – even if incidentally.

Conclusions

The present study demonstrates that prior knowledge supports memory for extrinsic context, or memory for extra-item details. Extrinsic context was operationalized as Remember responses and objectives source memory accuracy. In addition, the degree of prior knowledge stored for a given stimulus predicted the likelihood of recollecting extrinsic context along with the studied stimulus. The benefit of prior knowledge on memory for extrinsic context was not reproduced to the same extent by simply increasing exposure at encoding. Furthermore, prior knowledge supported the formation of durable memories, even under incidental encoding conditions, suggesting familiar stimuli are more efficiently encoded into memory. Importantly, prior knowledge was also associated with a subtle though reliable impairment in memory for the precise details of the studied item itself, or intrinsic context. This loss of precision for intra-item details cannot be easily accounted for by a purely resource-based account of memory encoding and likely requires the incorporation of a schema-based generalization mechanism. By examining extrinsic and intrinsic context separately, we demonstrate that resource and schema-based theories provide complementary, rather than contradictory, accounts of how prior knowledge influences memory detail.

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CRediT authorship contribution statement

B. Bellana: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **R. Mansour:** Investigation, Writing - review & editing. **N. Ladyka-Wojcik:** Investigation, Formal analysis, Writing - review & editing. **C.L. Grady:** Conceptualization, Writing - review & editing, Supervision, Funding acquisition. **M. Moscovitch:** Conceptualization, Writing - review & editing, Supervision, Funding acquisition.

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Appendix A. Supplementary data

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