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**Fractionating the reward-memory literature:
Instructed, item-related feedback, and item-unrelated feedback**

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Abstract

Over the last two decades, nearly one hundred studies have been published examining reward influences on memory. Implementations of reward-value procedures have varied markedly, as have other study characteristics, including images vs. words, intentional vs. incidental memory encoding, and recall vs. recognition tests. As such, the resulting state of the field has become unwieldy and somewhat difficult to identify consistent reward-memory effects from those that are inconsistent due to critical differences in the study methods. Here we provide an overview of these studies and fractionate their methods into three distinct procedures: instructed, item-related feedback, and item-unrelated feedback. Instructed studies tell participants of item-value associations during encoding with rewards earned during memory retrieval. In contrast, feedback studies ask participants to make responses during encoding, with rewards provided as feedback; memory retrieval itself is unrewarded. Some feedback studies require participants to make responses related to the to-be-remembered items, while others require participants to respond to an initial prompt before presenting an unrelated stimulus. While both procedures involve feedback, the first set of studies involves item-related feedback, and the second set has item-unrelated feedback. By fractionating the reward-memory literature into distinct procedures, an otherwise heterogenous mixture of study design characteristics becomes much more interpretable and the underlying cognitive mechanisms more clear. This additional clarity should improve predictions for future studies, as this framework helps identify which prior findings are more relevant, while also providing a summary of the current state of the field.

Keywords: reward, memory, motivation, value-directed remembering, episodic memory

Introduction

A growing literature has been investigating the effects of rewards on memory, generally showing that rewards can enhance item recognition and recall, though sometimes have more complex interactions in other memory tests. However, this literature is often cited as if these studies were generally consistent in methodology and results. Here we examined 89 experiments conducted across 44 papers, published between 2000 and 2020, to characterise this literature more precisely. We found that despite many critical differences between sets of studies, there are sufficient within-set consistencies. As such, we have attempted to ‘fractionate’ the literature to determine clearer patterns in the experimental designs used, with the further goal of identifying likely memory system mechanisms underlying different sets of studies.

Apparent from the overall literature—before fractionation—are the number of studies unraveling how rewards modulate memory during deliberate versus incidental encoding. Namely, that studies either instruct participants to encode stimuli for upcoming rewarded memory tests (e.g., Adcock et al., 2006; Hennessee et al., 2017, 2019) or ensures participants are unaware of upcoming memory tests with rewards being earned during the task itself (e.g., Rouhani et al., 2018; Wittmann et al., 2005, 2011). Converging findings have shown enhanced memory for high reward-associated stimuli under various conditions (e.g., Castel et al., 2002; Bowen et al., 2020a; Gruber et al., 2014; Stare et al., 2018), although with a few exceptions (e.g., Wittmann et al., 2005, 2011). Similarly, some studies combine these two ways of encoding by also testing source memory showing an interesting nuance of reward effects on memory (Elliott et al., 2020a; Murayama & Kitagami, 2014; Rouhani et al., 2018; Shigemune et al., 2010; Wimmer & Büchel, 2016), illustrating similar findings (i.e., better source memory for higher rewarding stimuli). Other apparent methodological differences found in the literature pertain to small, perhaps perceived as insignificant, differences in

experimental designs across studies. For instance, the type of stimuli used and the number of items encoded vary greatly among studies of reward and memory. Moreover, studies use different memory tests to study their hypotheses, particularly apparent across studies assessing deliberate versus incidental encoding. Lastly, some studies use points while others use money as incentive types (e.g., Adcock et al., 2006; Castel et al., 2002; Madan & Spetch, 2012; Murty & Adcock, 2016) with a few using other incentive types (e.g., trivia answers [Gruber et al., 2014] or food items [Gluth et al., 2015]).

First, we summarise several key studies within the reward-memory literature. We then propose that several distinct methodological procedures comprise this overall literature and attempt to fractionate this work. Finally, we discuss differences in underlying cognitive mechanisms that would be involved in these procedures and broader considerations.

Key Studies

(1) Castel et al. (2002) had participants associate reward values with items during encoding. Here the authors were interested in memory control and tested younger (in their twenties) and older adults (in their seventies) over a series of experiments. In the first experiment, participants were presented with 48 lists of twelve words preceded by point values (ranging from 1 to 12, presented in random order). Following the twelfth word, participants completed a verbal free recall task and had been instructed to prioritize words with the highest associated values to optimize their total score. Because previous research had demonstrated that older adults remember less content than younger adults, Castel and colleagues asked if older adults could exhibit control and selectively recall the highest value words. Selectivity was calculated based on participants' scores relative to chance and ideal performance, considering the number of words recalled (Watkins & Bloom, 1999). Younger adults recalled more words than older adults, but, unexpectedly, older adults showed greater selectivity than

younger adults. That is, older adults were better at selectively recalling the highest value words.

In the second experiment, the procedure was the same except for one critical change: point values were presented after the words (rather than concurrently). Presenting values after the corresponding words resembles direct-forgetting procedures by increasing the role of deliberate, strategic memory control. Results were consistent with findings observed from the initial experiment. A third experiment examined how the numerical points influenced memory, finding that older adults showed higher selectivity only when explicitly asked to maximize their score. In the fourth and final experiment, the role of retention interval was examined. List recall was tested immediately or after a 1-minute delay. Younger adults recalled more words than older adults in both test formats, although both groups performed worse during the 1-minute delayed recall. Notably, older adults only showed better sensitivity when memory was tested immediately after encoding but not following the 1-minute delay. This demonstrated that age-related differences in selectivity emerge when relying on short-term memory (i.e., younger adults dilute their selectivity by remembering more low-value words). Taken together, these findings highlight that older adults are more selective of what is encoded, but this information rapidly deteriorates as the time from encoding to retrieval increases. That is, older adults are only able to utilize their selectivity when retrieval occurs immediately after encoding.

Similar studies include Hennesse et al. (2017, 2019), Stefanidi et al. (2018), and Elliot and Brewer (2019).

(2) Adcock et al. (2006) similarly examined the influence of reward cues on encoding. Although fMRI data were collected to understand neural correlates of reward-memory effects, these are not discussed here. On each trial, participants saw a scene which was

preceded by either a high-value (\$5) or low-value (\$0.10) reward cue. Each reward level had 60 unique scenes resulting in participants studying a total of 120 scenes during encoding. The reward cues acted as motivational prompts because successful retrieval of the scenes during recognition meant participants would earn the associated reward. At the end of each trial, participants completed a distractor task before moving onto the next.

Memory was tested 24 hours after encoding using an old/new recognition procedure consisting of the 120 scenes previously seen during encoding and 120 new scenes. After making old/new judgments, participants provided confidence ratings for the quality of their memory (i.e., “remember”, “know”, “pretty sure”, or “guessing”). False alarms were penalized in order to discourage participants from responding ‘old’ to each scene. High-value scenes had overall higher hit rates than low-value scenes. Moreover, differences in hit rates between high- and low-value scenes were driven by the number of correct high-confidence responses (pooling “remember” and “know” responses), which were significantly more frequent for high- compared to low-value scenes. The results demonstrate that reward motivation differentially influences recognition memory as a function of reward cues where high-value stimuli become more memorable than low-value stimuli.

Similar studies from other research groups include Gruber and Otten (2010), Mason et al. (2017), and Bowen et al. (2020a).

(3) Wittmann et al. (2005) were interested in understanding the link between reward anticipation and its effect on memory formation; as with Adcock et al. (2006), fMRI data was collected, but related findings are not reported here. Participants were shown images of animate or inanimate objects on each trial and asked to provide a judgment (via button press) indicating if they expected a reward or not. Following each reward anticipation judgment, participants completed a number-comparison task in which they had to indicate if a presented

number was larger or smaller than 5. Trials were either rewarded or non-rewarded, where reward feedback for the rewarded trials was dependent on responses in the number-comparison task. Participants earned a small monetary amount if judgments were correct and within a dynamically adjusted response deadline; otherwise, they lost a small monetary amount (presented using a green upward or red downward arrow, respectively). Non-rewarded trials were illustrated by a question-mark, and visual feedback was not provided for the number-comparison task. At the end of the experiment, participants were given a surprise old/new memory test consisting of 30 images from the rewarded trials, 30 from non-rewarded trials, and 30 new images. Although participants were found to respond faster to rewarded than non-rewarded trials, they did not elicit better memory for the rewarded than non-rewarded images.

Participants returned three weeks later, where a second remember/know memory test was administered using the same images from the initial old/new memory test. The delayed memory test also acted as a source memory test after each remember/know judgment, as participants were also asked to indicate whether the image had first been presented during study or the first memory test. In this delayed memory test, participants were found to have better recognition for old images compared to distractors irrespective of reward condition. Old reward-predicting images were primarily classified as ‘remember’ responses and resulted in better performance in the source recognition task (i.e., the delayed remember/know memory test) compared to non-rewarding images. Non-rewarded images were at chance-level for the source memory test.

(4) Murayama and Kubandner (2011) also assessed reward anticipation and its effect on memory, but instead of using neutral stimuli, they used trivia questions. Trivia questions were normed for interesting-ness on a 7-point scale by 20 independent raters, who were not part of

the memory study (e.g., “What is the only planet in the solar system that rotates clockwise?”, “What is the national flower of Spain?”). Participants were assigned to either a reward or control group and completed an incidental learning task where they saw trivia questions, guessed the answer, and were then provided with the correct answer. For those in the reward group, each correct guess was associated with a small monetary reward. Once participants had seen all trivia answers, they engaged in a 10-minute filler task before completing a surprise memory test. Here participants were cued with each trivia question for 10 seconds and had to recall the correct answers; performance in the memory test was unrewarded. Participants recalled approximately the same number of answers in the immediate memory test regardless of condition.

One week later, participants returned to complete a second surprise, unrewarded memory test. Unlike in the immediate memory test, participants had different recall rates depending on the group in the delayed memory test. Moreover, recall rates were similar for interesting questions irrespective of group, but the reward group recalled more answers to uninteresting questions compared to the control group. Taken together, these findings suggest that the use of extrinsic motivation does not enhance memory immediately after encoding but can aid memory consolidation.

(5) **Madan et al. (2012)** assessed the effect of reward on implicit and explicit memory when learning from experience through a series of four tasks. In the value-learning task, participants learned to associate 36 words with high or low rewards over 13 blocks, each consisting of 18 choice trials. On each trial, participants were presented with two words (one high- and one low-value) and received feedback for the chosen word. Next, they completed a lexical-decision task (consisting of 36 trained words, 18 new, and 54 non-words), followed by a free-recall test, and, lastly, a value-judgment task. In the value-judgment task,

participants were presented with each word previously encountered in the initial learning task and judge the number of points each word was worth. As the experiment progressed, participants were found to choose the high-value word on every trial more consistently; starting at chance-level performance in the first block and ending at near ceiling-level performance. Reward value influenced both explicit and implicit memory measures, where high-value words were better recalled in the free-recall task as well as identified faster in the lexical-decision task, in comparison to low-value words, despite being learned equally well (highlighted by the value-judgment task). Moreover, while both memory systems were enhanced, participants who learned value associations earlier in the value-learning task were found to have greater implicit memory enhancements. In contrast, those who learned value associations later had increased value effects in the explicit memory test.

In a second experiment using the same initial value-learning procedure, participants then re-learned six lists of 9 words containing three high-value, three low-value, and three new words. After each list, participants completed a distractor task and then were asked to recall as many of the nine words as possible. Here it was found that the high-value bias from the initial value learning task persisted during learning in the new context. That is, previously learned high-value words negatively affected the ability to re-learn these words in new contexts, highlighting proactive interference.

A close follow-up study by Madan & Spetch (2012) assessed if better memory for high-over low-value words could be attributed to the reward values themselves or the values' salience. The study used the same design as Madan et al. (2012) but with three reward levels, rather than two, in Experiment 1, and six reward levels in Experiment 2. The study found evidence in favor of reward saliency causing memory enhancements as high- and low-reward words were both more memorable than intermediate-reward words (i.e., a quadratic or U-shaped function).

(6) **Wimmer and Shohamy (2012)** investigated if preferences for neutral stimuli could be increased via incidental association with rewarding stimuli; similar to several previously summarised studies fMRI findings are not reported here. This experiment consisted of three phases: incidental association, reward, and decision. In the incidental association phase, participants were shown pairs of pictures (S1 [face, scene, or body part] and S2 [patterned circles]) during which they completed a cover task where they had to determine if pictures were presented upside-down; the purpose of the task was for participants to form associative memories between the pair of neutral stimuli. None of the inverted pictures were used in the subsequent phases. Participants then completed a classical conditioning reward phase where half of the S2 images were followed by a monetary reward while a neutral outcome followed the other half. Critically, S1 stimuli were never shown in the reward association phase. Lastly, participants completed the decision phase, where they were asked to choose between pictures (both S1 or both S2). Here, one of the options had previously been associated with a rewarding outcome (either directly or incidentally), while the other option had been associated with a neutral outcome. (See Figure 1 of Wimmer & Shohamy, 2012, for an illustration of this procedure.)

As expected, participants chose the rewarding S2 items over the non-rewarding S2 items in the decision task. However, the decision bias favoring S1 items that had incidentally been associated with rewarding S2 items varied both within and across individuals, with some participants displaying a bias while others did not. This finding suggests that, in some cases, preferences of neutral stimuli can be increased when incidentally associated with stimuli that are known to be rewarding.

(7) **Gruber et al. (2014)** assessed how curiosity might enhance learning for incidental material by using trivia questions, similar to Murayama and Kubandner (2011). Participants first rated the likelihood they knew the answers to trivia questions and their curiosity to learn the answers, each on 6-point Likert scales. Curiosity for trivia answers was classified as low if rated as 1-3 and high if rated as 4-6. Participants gave curiosity ratings until 56 questions had been rated as high-curiosity and 56 questions had been rated as low-curiosity. Participants were then shown the trivia question in random order and provided with the answers. Critically, before receiving the trivia answers on every trial, participants were shown a face and asked to make yes/no judgments about whether they believed the person could answer the question. After seeing all 112 trivia answers, the experiment ended, and participants were asked to return the next day, where they were asked to complete a surprise recognition and free recall tests. The old/new recognition test consisted of the 112 previously presented, interleaved faces and 56 new faces; the free-recall test asked participants to recall as many of the trivia answers as possible.

Expectedly, participants had better memory for old faces compared to new faces, but, more importantly, participants showed better recognition for faces encountered during the high-curiosity questions. Likewise, answers to high-curiosity trivia questions were recalled significantly more than to low-curiosity answers. These findings illustrate that curiosity not only enhances learning for the rewarding outcome (i.e., the trivia answers), but *also* enhances incidental learning of task-irrelevant information.

(8) **Duncan and Shohamy (2016)** assessed how context familiarity influences encoding and retrieval during decision-making across three experiments. In the first experiment, participants were first exposed to five scenes in random order and made indoor-outdoor judgments four times for each scene to establish contextual familiarity, followed by a choice

task. In the choice task, each trial started by showing participants either a familiar or novel scene. Two objects were then placed on top of the scene, and participants were asked to choose one of the two objects. Participants received feedback for the chosen object in the form of a monetary incentive (\$0 – 1, in increments of 20¢). On 180 of the 360 trials, participants were shown an old object paired with a new one and had to rely on their memory to make informed decisions about which object to choose. On the other half of the trials, participants were shown two new objects. Importantly, objects were never presented with the same scene more than once.

The experiment showed that participants rely on past experiences to guide their choices as they were more likely to choose old high-value objects over new objects. Contextual familiarity resulted in different use of memory whereby high- and low-value objects were more likely to be chosen and avoided, respectively, in the familiar compared to the novel scene. Additional evidence was suggestive of retrieval and encoding being differentially affected depending on context. Specifically, learning about reward values (i.e., the outcome of a choice) in novel contexts was numerically (but not significantly) more likely to guide later choices. A replication experiment with a larger sample size replicated findings from Experiment 1 and, additionally, found reward learning within the novel context to be significantly more likely to guide future choices.

A second experiment used the same structure as Experiment 1, but scenes were separated from the choice stage between objects (i.e., choice options were no longer placed on top of the cued scenes). Additionally, participants were not pre-exposed to scenes to create a familiarity effect but instead had to experience them throughout the experiment. Scenes were categorized as novel during the first encounter and categorized as familiar on the second encounter. Participants completed 240 trials, and reward feedback ranged between \$0-1 in increments of 25¢. Choices were found to be influenced more by value memories when

participants saw a familiar scene than a novel scene. Moreover, the authors found evidence suggesting that successfully recognized a familiar scene played a critical role in establishing the contextual effect on choice.

Together, these findings highlight a double disassociation where a familiar context facilitates memory retrieval while a novel context facilitates memory encoding. However, this only occurs in cases where a previous scene is recognized as familiar.

Fractionating into Distinct Reward-Memory Procedures

Based on these key studies, as well as a comprehensive review of the literature (described later), we have classified the reward-memory approaches used in the literature generally belonging to one of two broad, yet distinct, procedures: instructed and feedback. See Figure 1 for an overview of these procedures and their key features.

Figure 1. Overview of the categorised procedures and key features.

In the **instructed** procedure, participants are shown rewards before, concurrently, or after to-be-remembered items (Adcock et al., 2006; Castel et al., 2002; Gruber & Otten, 2010; Hennessee et al., 2019). As such, to-be-remembered items are intentionally and

explicitly associated with the rewards. Critically, rewards are not *earned* during encoding but, instead, in the subsequent memory test. In this procedure, participants are informed that their memory will be tested, and successful remembering items will earn them the associated rewards—requiring deliberate rather than the incidental encoding of stimuli. This procedure relies on memory control processes and shares similar methods to directed forgetting and think—no-think procedures.

Conversely, the **feedback** procedure relies on rewards as outcomes during encoding, and most involve memory effects based on reward anticipation mechanisms. In these studies, participants are often not informed that their memory will be tested and do not necessitate deliberate encoding. To best interpret the literature, we further divide this procedure into two sub-procedures — item-related and item-unrelated. We refer to these studies collectively as ‘feedback’ because they rely on item-value learning through feedback and anticipation between what stimuli lead to which rewards (Duncan & Shohamy, 2016; Madan et al., 2012; Murty & Adcock, 2014; Wittmann et al., 2005). These procedures generally use a surprise and unrewarded memory test, where rewards are earned during encoding and participants are not informed about later memory tests, leading to incidental encoding of item-value associations. Because encoding occurs incidentally, studies can only have a single study-test cycle.

The **item-related feedback** procedure has been categorized as such because to-be-remembered *items are directly related to reward feedback*. Specifically, rewards are contingent on *choices* between to-be-remembered items such that rewards are based on item-related responses. Because rewards are based on item-related responses, participants can learn reward patterns (e.g., Madan et al., 2012). Conversely, in the **item-unrelated feedback** procedure rewards are not related to the to-be-remembered items; instead, rewards are contingent on performance in an unrelated reward task. Studies using item-unrelated

feedback typically present participants with to-be-remembered items before or within the unrelated reward task (Gruber et al., 2014; Wittmann et al., 2012). Studies using unrelated-item feedback have also used trivia answers as rewarding outcomes—intertwining rewards and curiosity, which is not sensible with the other procedures (e.g., Gruber et al., 2014; Murayama & Kuhbandner, 2011).

Notably, the two feedback procedures vary in the amount of uncertainty present on trials, with the item-unrelated procedure having more inherent uncertainty than the item-related procedure. When feedback is unrelated to the items, uncertainty is constant and cannot be learned—as trials in the unrelated, rewarded task are independent of each other. For example, learning the correct trivia answer to one question does not assist performance on a different question (e.g., Gruber et al., 2014). Similarly, when cues are reward-predictive ~80 percent of the time reward-uncertainty is still present (e.g., Wittmann et al., 2005). Conversely, when items are directly reward-related and repeated, learning these item-value associations influences behaviour on later trials. For example, knowing items are associated with high rewards increases the likelihood of choosing them over items with unknown item-value associations; the opposite pattern is found when items are associated with low rewards such that they are less likely to be chosen compared to items with unknown item-value associations (Duncan & Shohamy, 2016).

Admittedly, these three approaches are not sufficient to describe all reward-memory studies, for instance, Murayama and Kubandner (2011) and Wimmer and Shohamy (2012) do not clearly fit within these three approaches and will be discussed later. Nonetheless, this fractionation of the literature does otherwise fit nearly all considered studies.

Literature Review

A total of 44 studies with 89 experiments fitting within the fractionating framework were reviewed, plus an additional 6 studies (10 experiments) that were considered but did not fit within the fractionating framework.

Study Characteristics

Our goal was to first characterise the literature into different reward procedures, as described above—which we describe as ‘fractionation,’ and then examined how this related to other study characteristics. For instance, do studies that involve instructed reward cues versus feedback differ in if memory is tested with recall or recognition? Here we focused on characteristics that have been established as being important in influencing performance in memory studies.

In the memory literature, it is well known that recognition is easier than recall, thus increasing memory accuracy for studies using recognition tests (Kennedy, 1898; but see Tulving, 1968). This, naturally, is modified further by the number of stimuli needed to be encoded and stimuli type (e.g., Murdock, 1962; Naim et al., 2020), and the delay between encoding and retrieval (Brubaker & Naveh-Benjamin, 2014; Ebbinghaus, 1885). Central to our aim, by closely assessing these characteristics, we obtain better insight into the complexities of how these factors may interact, forming the basis for our fractionated procedures (e.g., see Fig. 2). Identified characteristics of importance included the use of different incentive types, stimulus types, number of stimuli studied, type of memory encoding, memory tests, study test-cycles, and delays between encoding and memory test. These characteristics across all included studies, and for each identified procedure, are included in Table 1.

Coincidentally, the characteristics we identified converge with Jenkins’ (1979) tetrahedral model of memory experiments. Specifically, Jenkins (1979) proposes that

memory experiments findings are influenced by a combination of the type of stimuli encoded (e.g., words), encoding conditions (i.e., how and where stimuli are encoded; e.g., being told rewards can be earned by making animacy judgments), retrieval conditions (i.e., how information is retrieved; e.g., recognition or recall), and participant sample (e.g., young or older adults).

Before fractionating the overall reward-memory literature, it seemingly consists of various differences in their experimental design (see the first row of Fig. 2). Across the 89 reviewed experiments, the primary incentive used in the literature is overwhelmingly money (47 experiments) followed by points (36 experiments). Of the remaining 6 experiments, incentives varied across a few possibilities, such as trivia answers or food items as incentives. Images were the primary stimuli type used, representing 48 of the 89 experiments (note, here ‘images’ includes scenes, objects, faces, and other types of images; see Table 1 for specific details). The remaining 41 experiments used word stimuli.

Of the 89 experiments, 47 used an incidental encoding paradigm, with the remainder used an intentional encoding paradigm, though a single study used both (in different phases of the study). Recognition memory tests were overwhelmingly represented in the literature (54 experiments), while 21 experiments used recall tests. Four experiments utilized both recognition and recall memory tests. Ten experiments tested memory used choices. Lastly, 67 of the reviewed literature uses single study-test cycles, with the rest using multiple study-test cycles. However, one study used both single and multiple study-test cycles as previously described (Madan et al., 2012).

Following our fractionation, the distribution of experimental design differences becomes clearer, illustrating patterns across the three different procedures. These patterns and distributions of experimental design differences across the procedures relative to the overall literature are shown in Figure 2.

Figure 2. Pie charts illustrating the relative number of studies with different procedural characteristics. See Table 1 for further details.

[Table 1 is included at the end of the document]

426 *Fractionating the literature*

427 As outlined above, the reward-memory literature may be perceived as a consistent literature
428 in which studies systematically assess reward-memory processes with few apparent
429 differences. However, such a view may be an oversimplification leading to
430 overgeneralizations, studies relying on distinctly different memory mechanisms, and
431 underemphasizing the importance of certain experimental design differences found in the
432 literature. Our fractionation provides an overview of less apparent differences among studies
433 when initially glancing at the literature and, furthermore, provides a framework
434 characterizing distinct procedures which capture most studies in the current literature. In
435 addition, fractionating provides an overview of how differences in experimental designs are
436 distributed among the emerged procedures (see Figure 2 for visual illustration across
437 fractionated procedures). Overall, the literature seemingly uses some incentive types
438 predominately more than others (e.g., money and points versus trivia and food items), with
439 the dominant memory test being recognition. The latter example perfectly corresponds to the
440 primary usage of images over words and relies slightly more on incidental rather than
441 intentional encoding. When fractionated, however, a unique pattern in experimental design
442 differences across sets of studies emerge. For example, although images may be the stimuli
443 type primarily used in the reward-memory literature as a whole, this can be attributed
444 primarily to specific set of studies; namely, the two feedback procedures (e.g., see second
445 column of Fig 2). That is, instructed studies assessing deliberate encoding primarily use
446 words as stimuli, whereas item-related feedback studies primarily use images while item-
447 unrelated studies solely use images. Again, note that, for simplicity, ‘images’ represent a
448 broad number of stimulus types, including scenes, objects, and faces, but these are
449 distinguished in Table 1.

Although money is used as the primary incentive type among the vast amount of feedback studies, instructed studies also heavily use money as an incentive type. However, more importantly, incentive types rarely used in the literature, namely trivia answers and food items, are highlighted by our fractionation to be specific to the two feedback procedures. Several item-unrelated feedback studies have used trivia answers as rewards because obtaining answers to unknown questions are inherently rewarding and prompts reward anticipatory responses (e.g., Gruber et al., 2014; Stare et al., 2018), which is one of the defining features of the procedure. A few item-related feedback studies use food items as these relate to memory in repeated preferential choice (Gluth et al., 2015) while N/A refers to studies in which making correct choices are treated as rewards (e.g., patients choosing the correct stimuli, Bayley et al., 2005) which is only possible with the item-related feedback procedure.

Memory is at the center of the literature, and the usage of different memory tests used across the literature probe different forms of memory (i.e., declarative and non-declarative). The overall literature seemingly relies primarily on testing recognition memory – and thereby primarily capturing declarative memory – and less on testing recall and even less so use both types of memory tests (e.g., Madan et al., 2012). However, the fractionation highlights that the intentional procedure captures declarative memory mechanisms, whereas the item-unrelated feedback procedure captures non-declarative memory mechanisms (specifically, associative learning). Uniquely, the item-related feedback procedure tests non-declarative similar to the item-unrelated procedure but, like the intentional procedure, can also test declarative memory by utilizing (cued and free) recall tests. Additionally, our fractionation also captures preference-based decisions where preferences are formed based on participants' past experiences with choice options resulting in variable rewards (e.g., Chakravarty et al.,

2019; Duncan & Shohamy, 2016). The item-related feedback procedure captures this set of studies and, arguably, represents a more ecologically valid link between reward and memory.

One critical aspect captured by our fractionation is the different use of study-test cycles among studies. Even though it is somewhat apparent from the overall literature that different sets of studies use different study-test cycles, this difference between sets of studies may either be neglected or viewed as unimportant in explaining reward-memory effects. Our fractionation highlights a balanced use of study-test cycles are only found with the instructed studies, while only single study-test cycles are for feedback studies (with few exceptions). The different use in study-test cycles across studies is dependent on the number of items that have to be and how these items are encoded. Specifically, repeated study-test cycles cannot be used with the item-unrelated feedback procedure because the underlying encoding mechanism would switch from incidental to deliberate encoding following the first cycle. Thus, repeated study-test cycles are used primarily by instructed studies – as they rely on intentional encoding – but has also been applied in item-related feedback studies to reveal novel insight into differences between declarative and non-declarative memory for the same stimuli (e.g., see Madan et al., 2012, Exp. 2). As such, multiple study-test cycles can be applied to the item-related and item-unrelated feedback studies, but it entails a switch in encoding mechanisms (i.e., from incidental to intentional).

The differential use and distribution of incentive types in the overall literature are well-reflected in the item-related feedback procedure, with studies primarily using monetary followed by point incentives. The fractionation also clearly illustrates that food items are only used as rewards in this procedure. Moreover, the procedure also includes one study (Bayley et al., 2005), which we define as having a ‘N/A’ incentive type. To reiterate, this study tested two amnesic patients making memory-dependent choices where correct choices were treated as rewards. In contrast with the overall literature (and the intentional procedure), the item-

related feedback procedure overwhelmingly uses images as stimuli, with about one-fourth of studies using words. This procedure also almost exclusively uses incidental encoding, with few studies using both intentional and incidental encoding – opposite to the intentional procedure. Compared to the overall literature, the item-related feedback procedure uses an approximately equal distribution of recognition and recall tests as well as choices contingent on past experiences with stimuli. Like the overall literature, this procedure primarily uses single study-test cycles and occasionally both single and multiple study-test cycles but never only multiple study-test cycles.

Similar to the overall literature, the item-unrelated feedback procedure primarily uses monetary incentives but rarely uses point incentives. Instead, obtaining the answer to a trivia question as an incentive is used with this procedure, which is not present in the other procedures. Compared to the overall literature, using trivia answers as rewards represents a greater fraction of the studies that fall within this procedure. In stark contrast to the overall literature, this procedure only uses incidental encoding, recognition memory tests, and single study-test cycles.

General Discussion

Here we thoroughly examined the reward-memory literature and have divided it into three methodological procedures. In doing so, we find distinctions in the underlying mechanisms that support each set of studies.

Instructed procedure

The instructed procedure uses rewards as instructional cues to form item-value associations where rewards can either be presented before or after a stimulus. Utilizing rewards as instructional cues is only possible as participants, prior to the experiment, have been explicitly instructed that their memory (recognition or recall) will be tested for the items, and

successful retrieval will earn them the associated rewards. Explicitly providing instructions to participants about reward structures incentivizes remembrance of as many stimuli as possible, thus heavily implicating memory control mechanisms. Indeed, Castel et al. (2002, 2007) illustrate differential encoding selectivity and strategic control among younger and older adults when maximizing earnings through intentional encoding. Specifically, older adults elicit superior selectivity through gist-based encoding and retrieval mechanisms relative to younger adults. Crucially, because rewards are earned during memory tests, studies testing recognition memory punish participants for false alarms to ensure they do not categorize all items as ‘old’ (e.g., Adcock et al., 2006). False alarms are only punished if participants are paid based on performance, whereas studies using hypothetical rewards (e.g., incentivizing accumulation of points without converting to real money) false alarms go unpunished (e.g., Elliot & Brewer, 2019; Hennessee et al., 2017, 2019).

The instructed procedure, unlike the two other procedures, is the only procedure to readily use repeated study-test cycles (note, however, study-test cycles are considered different for the item-related feedback procedure, as outlined below). Naturally, the use of multiple study-test cycles among instructed studies is only possible because participants are explicitly aware that their memory will be tested. Because memory is tested immediately after each cycle, intentional studies using multiple study-test cycles have smaller lists of stimuli that need to be encoded compared to studies using single study-test cycles (see Table 1 for an overview of list sizes). Conversely, when single cycles are used, it allows for assessing reward modulating effects following memory consolidation (e.g., Shigemune et al., 2010) or even contrasting reward modulating effects following initial encoding and memory consolidation (Bowen et al., 2020a).

When studying reward modulating effects on memory it can be difficult ruling out and differentiating between attentional and rehearsal effects. However, Shigmune et al.

(2017) used a slightly different method than the other reviewed intentional studies. Instead of showing value associations (i.e., high/low) during encoding, they were instead showed during retrieval. Thus, the authors modulated the retrieval process rather than encoding.

Item-related feedback procedure

The item-related feedback procedure relies on item-value associations where rewards are experienced through feedback and earned during the experiment. Because participants are not provided with information about reward structures, and instead have to rely on experience, encoding of item-value associations occurs incidentally. Because item-value associations are incidentally encoded through repeated exposure, item-related feedback study-test cycles differ from the two other procedures. Early in item-related feedback experiments, choices become contingent on memory of past experienced outcomes, and rather than considered as repeated study-test cycles they are considered to be a single study-test cycle for several reasons. They are considered single-study test cycles because memory is not explicitly tested at the end of each block, and item-value associations are continuously encoded incidentally. Regardless of whether outcomes are constant across the entire experiment (e.g., Madan et al., 2012) or contingent on probabilistic distributions (e.g., Daw et al., 2006), they are still incidentally encoded and used to update current representations of item-value associations and possible outcome distributions. That is, memory is tested indirectly on every trial through choice, but not explicitly with recall or recognition tests. Item-related feedback studies using point incentives instruct participants to accumulate as many points as possible. However, the reason for accumulating points may differ across studies such that some studies simply ask participants to earn as many points as possible (e.g., Daw et al., 2006) while others inform participants that, at the end of the experiment, points will be converted into money (e.g., Chakravarty et al., 2019).

To re-iterate, study-test cycles here are considered with respect to alternations in what is the main memory procedure. As such, some studies in this category have repeated cycles of the value learning task, but after the memory test (e.g., recall or recognition) begins, there is no subsequent return to any form of an encoding task. All of the reviewed item-related feedback studies have relied on single study-test cycles with the exception of one. Madan et al. (2012, Exp. 2) used a repeated study-test cycle by first having participants complete an incidental value learning task, followed by having participants re-learn words in a second deliberate memory encoding task. This becomes a repeated study-test cycle because participants are shown several lists, with a free recall test after each list. As such, participants are re-encountering previously learned stimuli in a new context, leading to reward carry-over effects. As described in more detail above, Madan et al. (2012) showed that following incidental learning through item-related feedback, memory was negatively affected during deliberate learning. Specifically, items incidentally associated with high rewards were harder for participants to deliberately re-learn despite knowing memory would be tested for the deliberately learned words. These findings highlight important mechanisms for memory whereby past incidental encoding of rewarding stimuli causes intrusions during deliberate learning, making it increasingly difficult to learn anew.

Some item-related feedback studies have been used to study amnesics illustrating a causal role of the hippocampus in memory-based choices for rewards. When learning about reward contingencies, patients perform at or below chance-level (Palombo et al., 2019) but importantly, this inability to successfully learn reward contingencies is only present during short periods of training and does not extend to long term training. Bayley et al. (2005) showed that when participants were trained over 18 weeks, they could successfully learn associations and make correct choices, though this performance collapsed once the original task was slightly modified.

599

600 *Item-unrelated feedback procedure*

601 The item-unrelated, similar to the item-related, feedback procedure does not provide explicit
 602 information about reward structures, and item-value associations are instead formed through
 603 feedback based on responses. The reward feedback participants receive based on their
 604 responses is not related to the to-be-remembered stimuli in this procedure (unlike item-related
 605 feedback) but, instead, related to a primary reward task. Thus, participants do not form item-
 606 value associations through repeated exposure with the same stimuli. Instead, reward
 607 outcomes from the primary reward task are associated with the unrelated stimuli, either
 608 shown before or after participants make judgments in the primary reward task. Because
 609 rewards are related to a primary reward task, rewards are earned during encoding where
 610 following memory tests assess modulating effects incidentally forming and encoding
 611 associations between seen stimuli and rewards. Even though all rewards are related to a
 612 primary reward task, it may often seem as though to-be-remembered items are related to
 613 reward outcomes directly (e.g., items placed on top of a ‘mat’ with probabilistic attributes;
 614 Wimmer et al., 2014).

615 As with the item-related feedback procedure, reward modulating effects on memory are
 616 influenced by reward anticipatory mechanisms because rewards are based on feedback. As
 617 such, the item-unrelated feedback procedure can use trivia answers as a unique incentive type
 618 which is not present in the other two procedures. Obtaining the answer to an unknown trivia
 619 question is inherently rewarding, especially when the accompanying curiosity for the trivia
 620 answer is high. As previously described, Gruber et al. (2014) elegantly illustrated how
 621 curiosity modulates memory through reward anticipatory mechanism by showing participants
 622 a series of trivia questions and answers – previously rated for curiosity – with interleaved to-
 623 be-remembered images. The authors showed that trivia answers associated with high

curiosity enhanced memory for incidentally encoding images, illustrating the intrinsic value of curiosity.

Studies that do not fit the framework

Admittedly, the three different procedures cannot encapsulate all reward-memory studies. For example, some studies can be considered hybrids since they use more than one of the three procedures. For example, Bornstein et al. (2017, Exp. 2) used an amalgamation between the intentional and item-related procedures, whereas Murayama and Kuhbandner (2011) use a hybrid design of the intentional and item-unrelated procedures. In a similar vein, Wimmer & Shohamy (2012) created an experimental paradigm that can be considered a hybrid of all three procedures. Our framework is dependent on testing item memory either through recognition, recall, or memory-guided choices. However, Wimmer and Büchel (2016) only tested participants' memory for incidentally encoded images through a value memory test and did not explicitly test item memory. Although item memory was tested in a subsequent fMRI experiment, it was preceded by a value memory test, potentially confounding the item memory test. Similarly, Miendlarzewska et al. (2020) only tested source memory but not item-memory, and, as such, the study does not fit with either of the three procedures. Another study used trivia knowledge as rewards but did not inform participants their memory would be tested nor used interleaved items for incidental encoding like other item-unrelated feedback studies (McGillivray et al., 2015).

Mechanisms underlying identified procedures

While we acknowledge that some prior reviews have attempted to characterise the reward-memory literature as well, the field has advanced markedly since these articles were published. Of particular relevance is Shohamy and Adcock (2010) and Miendlarzewska et al.

(2016). However, both of these reviews focused on specific neurobiological mechanisms, rather than classifying the procedures used. Moreover, in 2010, only 12 of the 89 experiments overviewed here had been conducted; by the end of 2015, this rose to 30 experiments. Even then, this is not to say that all of these prior 30 studies were discussed in this previous review, but rather to demonstrate that the literature has been rapidly growing, particularly using cognitive psychology, rather than neuroimaging. 59 of the 89 experiments included in the current review were published between 2016 and 2020.

The purpose of our fractionation was to illustrate, in part, that the overall reward-memory literature is made up of distinct procedures. By fractionating the literature, we have identified the key characteristics of the many study procedures into three. From the previous descriptions of these procedures, it should be apparent to the reader that the procedures rely on different underlying mechanisms for encoding to-be-remembered stimuli. The mechanism enhancing memory for high-reward stimuli in one procedure is different from the other two procedures despite overlap between procedures.

Central to the **instructed** procedure is the awareness that rewards are only earned for successful memory retrieval. In other words, memory control during encoding is critical. This awareness promotes selective encoding such that participants maximize their earnings during memory testing. In these studies, participants ought to selectively encode high reward (relative to low reward) associated stimuli (as highlighted in Castel et al., 2002). Selective encoding reward-item associations is dependent on utilizing cognitive control mechanisms such that increased attentional resources are allocated to high-rewarding over low-rewarding stimuli. As such, performance in this procedure is closely related to cognitive control mechanisms and executive function (Bajo et al., 2021; Chiew & Braver, 2017; Ravizza & Conn, 2021). It has been suggested that this prioritization is, at least partly, driven by arousal where memory for goal-relevant stimuli is enhanced (i.e., high reward-associated stimuli),

while memory for less important stimuli (i.e., low reward-associated stimuli) is suppressed (Mather & Sutherland, 2011). This procedure may bear some similarities with directed-forgetting paradigms, though assigning a penalty for retrieval (i.e., a negative value for memory) can create conflict between cognitive control and prioritization (see Bowen et al., 2020b).

Conversely, in the two **feedback** procedures, reward-item associations are learned through feedback and rely on associative learning. As such, these procedures rely primarily upon operant conditioning mechanisms rather than cognitive control. Memory enhancement of reward-item associations is dependent on the arousal associated with reward-prediction errors (Clewett & Mather, 2014; Schultz, 1998; Shohamy & Daw, 2015). Reward anticipation is more common in the item-unrelated feedback compared to the item-related feedback procedure due to differences in the sequence of the to-be-remembered stimulus, choice, and reward feedback. Typically, in the item-unrelated feedback procedure, participants make judgments about the to-be-remembered stimuli followed by the reward task (e.g., Wittmann et al., 2005) leading to a longer anticipation period—unlike in the item-related feedback studies. Thus, choices in the two procedures are dependent on information evoking old associations in both procedures; associations which are reinforced through prediction errors where arousal from prediction errors enhance memory for task-relevant stimuli.

There are exceptions where item-unrelated feedback studies may not rely on operant conditioning mechanisms but solely on reward anticipation mechanisms. Studies involving trivia questions and answers (e.g., Gruber et al., 2014) are unlikely to use operant conditioning mechanism as judgments about to-be-remembered stimuli are unrelated to obtaining the trivia answers. Instead, memory enhancements for these stimuli are driven solely by the reward anticipation mechanisms through a specific reward-anticipation process, curiosity.

699

700 *Insights into reward-memory study design*

701 **Intentional procedure and source memory.** As outlined above, the instructed procedure
 702 relies on intentional encoding of reward-item associations with rewards earned during
 703 subsequent memory tests. However, a sub-set of the reviewed intentional studies also assess
 704 source memory for the target items. Crucially, these studies either have participants
 705 intentionally encode source memory concurrently with the to-be-remembered items (Elliott et
 706 al., 2020a.; Shigemune et al., 2013) or have participants intentionally encode to-be-
 707 remembered items but incidentally encode source memory (Hennessee et al., 2017, Exp. 3).
 708 Thus, although the intentional procedure is dependent on informing participants about
 709 subsequent memory tests, this procedural characteristic is limited to only the target stimuli
 710 and not necessarily source memory. Capturing source memory – be it encoded intentionally
 711 or incidentally – reveals crucial information about underlying memory processes and reward
 712 interactions when deliberately attending and encoding certain sets of stimuli. Unsurprisingly,
 713 source memory is enhanced when successful retrieval results in reward or lack of punishment
 714 (Shigemune et al., 2013) and for items associated with high compared to low rewards where
 715 Remember/Know memory correlates with source memory (Elliott et al., 2020a). Crucially,
 716 however, memory for low-value associated source memory is enhanced when source memory
 717 is encoded incidentally rather than intentionally (Hennessee et al., 2017).

718 Taken together, this is suggestive of a common encoding and retrieval mechanism for
 719 the two types of memory but only when source memory is encoded intentionally (Elliott et
 720 al., 2020a). These findings suggest a mechanism where awareness of source memory has
 721 future utility lead to deliberate encoding of advantageous associated source items (e.g., high
 722 rewarding items). In contrast, disadvantageous associated source items are prioritized during
 723 incidental encoding, likely reflecting an implicit memory mechanism of which items to avoid

in the future. The latter mechanism is further cooperated by findings from the item-related feedback procedure assessing incidental encoding of source memory. That is, better source memory for low reward gambles and partners associated with low offers in the dictatory game (Murty et al., 2016) where children and adults elicit better source memory for non-rewarding than rewarding items while adolescents have relative equal well source memory for both (Katzman & Hartley, 2020). However, source memory has recently been shown to be enhanced for items associated with high risk (Rouhani et al., 2018).

Differences in cognitive mechanisms associated with small procedural changes. The instructed procedure is accompanied by reward certainty, participants know what rewards are obtained for successful retrieval during memory tests promoting memory control. Mason et al. (2017) used the instructed procedure but introduced reward *uncertainty* where deterministic reward words were cued by ‘0’ or ‘20’ while probabilistic reward words were cued by ‘0/20’. In Experiments 2 and 3, uncertainty was resolved by providing participants with feedback after making word judgments, making them aware of the rewards that could be earned for successful retrieval during the subsequent memory test. As rewards were earned during the memory test and participants were informed their memory would be tested, we categorized the study as using the intentional procedure. However, with a minor modification to the experimental design, this study would have been categorised as item-unrelated feedback procedure. That is, had rewards been earned during encoding rather than at test and had participants not been informed their memory would be tested the study would have been sufficiently different to not be considered an instructed procedure. In this alternate study, rewards would still be contingent on the outcome of gambling cues and not directly linked to the word judgment task. Therefore, participants would be unable to learn the reward patterns due to the uncertainty of which of the two tasks lead to the reward. Such a minor change

results in different memory mechanisms, where *reward anticipation* plays a more central role and words are incidentally encoded rather than intentionally.

Forgotten studies. The present review primarily focused on the contemporary reward memory research, i.e., 2000 to present day. However, a surprising amount of reward-memory studies were conducted in the 1960s and 70s that are generally not acknowledged (but see Madan et al., 2012; Madan, 2017). These studies largely fit within either the instructed or item-related feedback approaches. Briefly, the *instructed* studies presented explicit instructional cues indicating the reward value to be earned for successful recall (e.g., Weiner & Walker, 1966; Weiner, 1966; Tarpay & Glucksberg, 1966, 1968; Loftus & Wickens, 1970; Eysenck & Eysenck, 1982). The second set of studies in this period involved presenting two stimuli and rewards were earned for choosing the higher-value item (e.g., Estes, 1966, 1972; Humphreys et al., 1968; Allen & Estes, 1972; Medin, 1972), and served as the primary inspiration for some recent studies (Madan et al., 2012; Madan & Spetch, 2012).

Conclusion

By fractionating the reward-memory literature into distinct procedures, an otherwise heterogeneous mixture of study design characteristics becomes much more interpretable and the underlying cognitive mechanisms more clear. This additional clarity should improve predictions for future studies, as this framework helps identify which prior findings are more relevant, while also providing a summary of the current state of the field.

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Table 1. Methodological details for characteristics known to influence memory for included studies, grouped by categorised procedure.

Paper, Experiment Number	Incentive	Stimuli	Number of Stimuli per Cycle	Memory Encoding	Memory Test	Study-Test Cycles	Test Delay
<i>Instructed</i>							
Adcock et al. (2006)	Money	Scenes	120	Intentional	Recognition	Single	24h
Gruber & Otten (2010)	Money	Words	240	Intentional	Recognition	Single	15 min
Kuhl et al. (2010)	Money	Object pairs	28	Intentional	Recall	Repeated	Immed
Wolosin et al. (2012)	Money	Object pairs	30	Intentional	Recall	Repeated	Immed
Shigemune et al. (2010)	Money	Scenes and faces	40	Intentional	Recognition	Single	24h
Shigemune et al. (2013)	Money	Words	90	Intentional	Recognition	Repeated	Immed
Shigemune et al. (2017)	Money	Word pairs	256	Intentional	Recognition	Single	10 min
Bowen et al. (2020a), Exp. 1	Money	Scenes	120	Intentional	Recognition	Single	10 min & 24h
Bowen et al. (2020a), Exp. 2	Money	Scenes	120	Intentional	Recognition	Single	10 min & 24h
Bowen et al. (2020a), Exp. 3	Money	Scenes	120	Intentional	Recognition	Single	10 min & 24h
Bowen et al. (2020b), Exp. 2	Money	Words	90	Intentional	Recognition	Single	5 min
Bowen et al. (2020b), Exp. 3	Money	Words	90	Intentional	Recognition & recall	Single	5 min
Bowen et al. (2020b), Exp. 4	Money	Words	90	Intentional	Recognition & recall	Single	5 min
Castel et al. (2002), Exp. 1	Points	Words	12	Intentional	Recall	Repeated	Immed
Castel et al. (2002), Exp. 2	Points	Words	12	Intentional	Recall	Repeated	Immed
Castel et al. (2002), Exp. 3	Points	Words	12	Intentional	Recall	Repeated	Immed
Castel et al. (2002), Exp. 4	Points	Words	20	Intentional	Recall	Repeated	Immed
Castel et al. (2007), Exp. 1	Points	Words	16	Intentional	Recognition & recall	Repeated	Immed
Castel et al. (2007), Exp. 2	Points	Words	16	Intentional	Recognition & recall	Repeated	Immed
Castel et al. (2016), Exp. 1	Money	Faces	14	Intentional	Recall	Repeated	Immed
Castel et al. (2016), Exp. 2	Money	Faces	14	Intentional	Recall	Repeated	Immed
Cohen et al. (2016)	Points	Words	24	Intentional	Recall	Repeated	Immed
Hennessee et al. (2017), Exp. 1	Points	Words	90	Intentional	Recognition	Single	5 min
Hennessee et al. (2017), Exp. 2	Points	Words	90	Intentional	Recognition	Single	5 min
Hennessee et al. (2017), Exp. 3	Points	Words	90	Both	Recognition	Single	5 min
Hennessee et al. (2019), Exp. 1	Points	Words	48	Intentional	Recognition	Single	Immed
Hennessee et al. (2019), Exp. 2	Points	Words	48	Intentional	Recognition	Single	Immed
Hennessee et al. (2019), Exp. 3	Points	Words	48	Intentional	Recognition	Single	Immed
Spaniol et al. (2013)	Money	Scenes	124	Intentional	Recognition	Single	24h

Stefanidi et al. (2018), Exp. 1	Points	Words	10	Intentional	Recall	Single	Immed
Stefanidi et al. (2018), Exp. 2	Points	Words	10	Intentional	Recall	Repeated	Immed
Stefanidi et al. (2018), Exp. 3	Points	Words	10	Intentional	Recall	Repeated	Immed
Stefanidi et al. (2018), Exp. 4	Points	Words	10	Intentional	Recall	Repeated	Immed
Elliott & Brewer (2019), Exp. 1	Points	Words	40	Intentional	Recognition	Repeated	Immed
Elliott & Brewer (2019), Exp. 2	Points	Words	40	Intentional	Recognition	Repeated	Immed
Elliott & Brewer (2019), Exp. 3	Points	Words	40	Intentional	Recognition	Repeated	Immed
Elliott et al. (2020a), RK	Points	Words	40	Intentional	Recognition	Repeated	Immed
Elliott et al. (2020a), Source	Points	Words	40	Intentional	Recognition	Repeated	Immed
Elliott et al. (2020b)	Points	Words	40	Intentional	Recognition	Repeated	Immed
Mason et al. (2017), Exp. 1	Money	Words	204	Intentional	Recognition	Single	24h
Mason et al. (2017), Exp. 2	Money	Words	204	Intentional	Recognition	Single	24h
Mason et al. (2017), Exp. 3	Money	Words	204	Intentional	Recognition	Single	24h
Mason et al. (2017), Exp. 4	Money	Words	100	Intentional	Recognition	Single	24h

Item-Related Feedback

Madan et al. (2012), Exp. 1	Points	Words	36	Incidental	Recall	Single	Immed
Madan et al. (2012), Exp. 2	Points	Words	36/9	Both	Recall	Both	5 min
Madan & Spetch (2012), Exp. 1	Points	Words	36	Incidental	Recall	Single	Immed
Madan & Spetch (2012), Exp. 2	Points	Words	36	Incidental	Recall	Single	Immed
Chakravarty et al. (2019), Exp. 1	Points	Words	48	Incidental	Recall	Single	Immed
Chakravarty et al. (2019), Exp. 2	Points	Words	36	Incidental	Recall	Single	Immed
Chakravarty et al. (2019), Exp. 3	Points	Words	36	Incidental	Recall	Single	Immed
Duncan & Shohamy (2016), Exp. 1	Money	Objects	540	Incidental	Choice	Single	Immed
Duncan & Shohamy (2016), Exp. 2	Money	Objects	360	Incidental	Choice	Single	Immed
Duncan & Shohamy (2016), Exp. 3	Money	Objects	540	Incidental	Choice	Single	Immed
Duncan et al. (2019), Exp. 1	Money	Objects	543	Incidental	Choice	Single	Immed
Duncan et al. (2019), Exp. 2	Money	Objects	460	Incidental	Choice	Single	Immed
Daw et al. (2006)	Points	Objects	4	Incidental	Choice	Single	Immed
Rouhani et al. (2018), Exp. 1	Money	Scenes	16	Incidental	Recognition	Single	5 min
Rouhani et al. (2018), Exp. 2	Money	Scenes	30	Incidental	Recognition	Single	5 min
Rouhani et al. (2018), Exp. 3	Money	Scenes	30	Incidental	Recognition	Single	5 min
Gluth et al. (2015)	Food	Objects (Snacks)	6	Incidental	Recall	Single	Immed
Raymond & O'Brien (2009), Exp. 1	Money	Faces	100	Incidental	Recognition	Single	Immed

Raymond & O'Brien (2009), Exp. 2	Money	Faces	100	Incidental	Recognition	Single	Immed
Katzman & Hartley (2020)	Points	Objects	120	Incidental	Recognition	Single	24h
Palombo et al. (2019), Exp. 1	Points	Characters	8	Incidental	Choice	Single	Immed
Palombo et al. (2019), Exp. 2a	Points	Characters	8	Incidental	Choice	Single	Immed
Palombo et al. (2019), Exp. 2b	Points	Characters	4	Incidental	Choice	Single	Immed
Bayley et al. (2005)	N/A	Object pairs	16	Incidental	Choice	Single	2/week, many weeks
<i>Item-Unrelated Feedback</i>							
Wittmann et al. (2005)	Money	Objects	120	Incidental	Recognition	Single	Immed & 3 weeks
Wittmann et al. (2011), Exp. 1	Money	Words	150	Incidental	Recognition	Single	24h
Wittmann et al. (2011), Exp. 2	Money	Words	120	Incidental	Recognition	Single	24h
Wimmer et al. (2014)	Money	Objects	200	Incidental	Recognition	Single	24h
Gruber et al. (2014), Exp. 1	Trivia	Faces	112	Incidental	Recognition	Single	20 min
Gruber et al. (2014), Exp. 2	Trivia	Faces	112	Incidental	Recognition	Single	24h
Stare et al. (2018)	Trivia	Faces	112	Incidental	Recognition	Single	Immed or 12h
Fandakova & Gruber (2019)	Trivia	Faces	60	Incidental	Recognition	Single	20 min
Murayama & Kitagami (2014), Exp. 1	Money	Objects	60	Incidental	Recognition	Single	Immed or 1 week
Murayama & Kitagami (2014), Exp. 2	Money	Objects	60	Incidental	Recognition	Single	1 week
Murty & Adcock (2014)	Money	Objects	40	Incidental	Recognition	Single	30 min
Murty et al. (2016), Exp. 1	Money	Houses	60	Incidental	Recognition	Single	20 min
Murty et al. (2016), Exp. 2	Money	Faces	60	Incidental	Recognition	Single	20 min
Murty et al. (2016), Exp. 3	Money	Houses	60	Incidental	Recognition	Single	10 min
Murty et al. (2016), Exp. 4	Money	Faces	60	Incidental	Recognition	Single	10 min
Murty et al. (2016), Exp. 5	Money	Houses & Faces	120	Incidental	Recognition	Single	20 min
Braun et al. (2018), Exp. 1	Money	Objects	192	Incidental	Recognition	Single	15 min or 24h
Braun et al. (2018), Exp. 2	Money	Objects	192	Incidental	Recognition	Single	24h
Braun et al. (2018), Exp. 3	Money	Objects	192	Incidental	Recognition	Single	24h
Braun et al. (2018), Exp. 4	Money	Objects	192	Incidental	Recognition	Single	24h
Swirsky et al. (2020)	Points	Objects	144	Incidental	Recognition	Single	20 min
Cheng et al. (2020), Exp. 1	Money	Objects	160	Incidental	Recognition	Single	24h
Cheng et al. (2020), Exp. 2	Money	Objects	160	Incidental	Recognition	Single	Immed