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Effects of survival processing on list method directed forgetting

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ABSTRACT
Two experiments examined the effects of directed (intentional) forgetting on information processed for its survival value. Experiment 1 used the list-method directed forgetting procedure in which items processed for their relevance to survival, moving house or pleasantness were followed by the cue to remember or forget. Following the encoding of a second list, free-recall of both lists showed that survival encoding brought about greater remembering (after the remember cue) and forgetting (after the forget cue). Experiment 2 also used the list-method and manipulated mental context reinstatement prior to recall. Although this manipulation was effective in enhancing memory, more directed forgetting was again shown in the survival condition. In both experiments the effects of survival processing were shown also in free-recall "remember" (vs. "know") responses, indicative of the retrieval of associative or contextual details. The mechanisms that might underpin these were evaluated and considered in relation to future work.

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Survival processing; directed forgetting; memory inhibition; context reinstatement; remember-know procedure

Overview of current research

The research presented here is concerned with the effects of adaptive memory processing on subsequent attempts to intentionally remember or forget information.

Particularly, how survival processing might potentially influence memory by making it more or less accessible to subsequent recall. Currently, no experiments have been conducted to assess how stimuli processed for survival value are impacted upon by controlled efforts to forget. Consequently, the present research examined this in the context of list-method directed forgetting and the qualities of the memory experience during recall by use of the remember-know procedure.

Evolution and adaptive cognition

If cognitive systems evolved, then they should have been fashioned by the same natural selection processes that have worked on physical attributes and anatomy (Nairne & Pandeirada, 2008). A consequence of this line of reasoning is that these systems can be considered the outcomes of evolutionary selection pressures and thus adaptive within those contexts. In line with this analysis, if memory systems have developed across evolutionary time, they should also exhibit features that reflect the outcomes of those developments and adaptions. These adaptions can be reflected in a variety of ways including: (i) enhanced mnemonic performance for certain types of stimuli and the processing of such stimuli in a manner that increases reproductive fitness (Nairne & Pandeirada, 2008, 2010), (ii) involuntary forgetting (Kuhl et al., 2007; Nørby, 2015), (iii) intentional or motivated forgetting (Bjork, 1989; Yang et al., 2013), and (iv) memory distortion (Schacter et al., 2011).

From the perspective of this research, the function of both memory enhancement and diminution reflects the workings of adaptive mechanisms that have enhanced fitness and survival over evolutionary time (e.g., Klein et al., 2002). The experiments reported here take this perspective by considering the joint contribution to memory performance of procedures claimed to be adaptive and to either enhance (survival encoding) or reduce (directed forgetting) memory.

Survival processing and memory

Survival processing denotes the cognitive activities employed to assess the survival relevance of stimuli (Nairne et al., 2007). Recent work has demonstrated that this form of processing can enhance memory beyond that obtained by other "deep" encoding tasks. For instance, Nairne et al. (2007) required subjects to rate the referents of a list of words (which themselves had no inherent relationship to survival) in terms of their relevance to assisting their personal survival if they were stranded in the grasslands of a foreign place. Compared to two other conditions, that fostered deep processing (rating words for their relevance to moving to a new house or pleasantness), the survival task brought about superior memory in a surprise free-recall test.

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This finding has been replicated and extended across numerous comparison tasks, (e.g., Nairne et al., 2008), tests (e.g., Kang et al., 2008; Kroneisen & Bell, 2018; Nairne et al., 2012), and stimuli (e.g., Otgaar et al., 2010). Although exceptions have been noted in face memory (Savine et al., 2011) and implicit memory (Tse & Altarriba, 2010), the original findings have proven to be robust (Scofield et al., 2018).

Under some conditions, memory needs to be persistent and show durability across extended retention intervals. This potentially provides an advantage as the constant forgetting of survival relevant information or environmental resources could hardly be considered adaptive. If so, one would expect the survival processing effect to outlast the short delays spanning a few minutes as typically used in memory research. Empirical evidence in favour of this has come from work in which the delay between study and test has been extended over 24 h or more. For example, Raymaekers et al. (2014) found the survival advantage was maintained over a period of 24 and 48 h. Although forgetting was observed across all conditions, the magnitude of forgetting was comparable for the survival and control conditions. Other work has found similar effects (Abel & Bäuml, 2013; Munetsugu & Horiuchi, 2015) and extended findings to include location memory (Clark & Bruno, 2016) and detailed recollective memory (Parker et al., 2019). Consequently, the survival processing advantage is preserved over extended delays of at least 48 h and suggests the size of the effect can be maintained across the passage of time.

While the survival processing advantage has been reproduced many times, the nature of the mechanisms that underpin this advantage are more contested. The ultimate, or distal explanation, is founded in terms of evolutionary history and the fine tunings that have arisen from selection pressures over this time (Nairne et al., 2008; Nairne & Pandeirada, 2016). Accounts like these are obviously difficult to test directly and much cognitive work has instead focussed on *proximate* explanations of the survival processing effect. These explanations make reference to cognitive activities that are known to be important for retention such as relational and item-specific processing (Burns et al., 2011), richness of encoding (Kroneisen & Erdfelder, 2011), gist-processing (Otgaar et al., 2010), planning (Klein et al., 2011), and self-referential processing (Klein, 2012). These accounts do not necessarily weaken the evolutionary explanation as it is possible that more basic cognitive processes have been co-opted to assist when survival priorities are relevant (Nairne & Pandeirada, 2016).

Adaptive forgetting

Forgetting has also been considered within an adaptive framework that emphasises the importance of *not* remembering all encoded material (Kuhl et al., 2007; Nørby, 2015). Some examples include the need to forget emotional experiences, redundant knowledge or information that is no longer correct (Nørby, 2015). Although forgetting is often considered to be an involuntary by-product of delay or interference, it can also come under voluntary control. Directed forgetting refers to those situations when encoded information needs to be *intentionally* disregarded. This form of forgetting is also considered to be adaptive in that it provides a basis for memory updating (Bjork, 1978, 2014; Pastötter et al., 2017). This allows for memory representations to be in-line with present goals and free from irrelevant or outdated information. This form of forgetting can be assessed in experimental paradigms that require encoded information to be either retained or disregarded by the presentation of remember instructions or forget instructions. This can be on either a stimulus-by-stimulus basis (item-method directed forgetting) or after a sequence of stimuli (list-method directed forgetting).

The research here made use of the list-method procedure. This choice was guided by accounts of directed forgetting in which differential emphasis is placed upon encoding and attentional mechanisms (item-method) and processes that occur *following* encoding into memory (list-method) (e.g., Basden et al., 1993; MacLeod, 1998; Sahakyan et al., 2013). Indeed, it has been argued that item-based directed forgetting is not true forgetting but represents differences in motivation to learn and differential encoding (e.g., Bancroft et al., 2013; Johnson, 1994). However, with the list method it is difficult to explain the range of findings by refence to encoding differences only. This is because an entire sequence of items has already been stored in memory prior to the cue to forget or remember. Thus, differential encoding and attentional mechanisms that could operate on an item-by-item basis are of lesser importance. In the present work, the concern is with the effects of survival processing on subsequent *post-encoding* operations such as instructions to forget once the information has been acquired.

In a typical list-method directed forgetting experiment, subjects are initially asked to encode a list of items (List 1). Subsequently, they are presented with a cue that indicates this list needs to be remembered (R-cue) or forgotten (F-cue) as it is no longer relevant (the precise instructions and procedures for the F-cue vary across experiments). Following the delivery of either of these cues, a second list is presented with instructions to remember this list. Finally, memory is assessed for both Lists 1 and 2 (e.g., Bjork, 1989). Typical findings are: (i) reduced memory for List 1 items after the F (vs. R) cue, especially on tests of free-recall and, (ii) enhanced memory for List-2 items following the F-cue. These are referred to as the costs and benefits of directed forgetting respectively (Sheard & MacLeod, 2005), with the former being of primary relevance in the current experiments.

Several factors have been shown to influence the magnitude of the costs of directed forgetting. For example, Pastötter and Bäuml (2007) found the costs to be dependent on the post-cue encoding of the second list; costs were eliminated when no additional encoding took place. Divided attention during List 2learning also reduces List 1 costs (Macrae et al., 1997), as does the presence of associative relations between the lists (Conway et al., 2000) or category cues when the lists comprise of category exemplars (Lehman & Malmberg, 2011). Thus, List 1 costs are not an obligatory consequence of the F-cue but can vary as a function of the experimental parameters.

Like survival processing, the empirical demonstration of directed forgetting effects and its boundary conditions are well documented. However, the mechanisms that underlie the effects have been more contested. The two dominant accounts are the retrieval inhibition and context change explanations. The former asserts that the presentation of the F-cue serves to implement an active inhibitory process that suppresses the accessibility of List 1 items and hence results in directed forgetting costs (e.g., Anderson, 2005; Bjork, 1989; Conway et al., 2000; Geiselman et al., 1983). An alternative explanation posits that such costs can be accounted for by non-inhibitory mechanisms. Particularly, forgetting of List 1 items arises because the cue to forget creates an internal context change prior to List 2 encoding. Following the final request to recall all items, the mental context established for List 2 mismatches that for List 1 and accordingly the accessibility of List 1 is reduced (Sahakyan & Delaney, 2005; Sahakyan & Kelley, 2002). Supportive evidence has accumulated concerning both accounts, thus making a clear demarcation between the two difficult (Abel & Bäuml, 2019).

Experiment 1

To date, survival processing and directed forgetting have not been examined together. Given the explicit adaptationist perspective of the former, and the fact that adaptationist accounts of intentional forgetting can be made, a joint appraisal of these ideas is important. This would allow for the establishment of further boundary conditions of each and an evaluation of the dynamic interplay of memory enhancement and diminution.

To this end, the first experiment examined the effects of directed forgetting on the free-recall for a set of words (List 1) processed under the *incidental* learning conditions of survival, moving or pleasantness rating. Although directed forgetting research has mainly made use of *intentional* learning instructions, some previous work has examined incidental learning conditions and has found results consistent with intentional learning (e.g., Geiselman et al., 1983; Power et al., 2000; Sahakyan et al., 2008; Sahakyan & Delaney, 2005).

In addition to assessing overall recall, a finer-grained assessment of memory was undertaken by use of the remember-know procedure (Gardiner et al., 1998; Tulving, 1983). Though mainly used in tests of recognition memory (e.g., Yonelinas, 1999, 2002), the procedure has recently been applied to free-recall (e.g., McCabe et al., 2011; McDermott, 2006). The rationale for using this procedure was that memory retrieval is thought to be dependent on different mnemonic processes that result in different states of awareness. Particularly, "remember" responses indicate the retrieval of contextual details from the study episode. In contrast, "know" responses designate confidence that the stimulus appeared earlier in the absence of the recollection of precise details.

In separate strands of research, both survival processing and R-cues have been shown to increase "remember" (vs. "know") responses in recognition memory and consequently provide information about the contributions of different states of awareness to overall mnemonic outcomes (e.g., Gardiner et al., 1994; Munetsugu & Horiuchi, 2015; Parker et al., 2019). To date, no experiments have considered the combined impact of both survival processing and directed forgetting on remember-know responses on free-recall, thus the present work addresses this limitation.

The principal concern of Experiment 1 was how survival processing influences the magnitude of directed forgetting. In relation to this, several outcomes are possible. Firstly, it could be argued that List 1 costs would be eliminated or very much reduced by survival processing. This would follow from the typical findings that information processed in terms of its fitness relevance is exceptionally well retained on tasks of explicit memory and is more memorable than most other established encoding procedures (Nairne & Pandeirada, 2016). In fact, it has been labelled as the "best of the best" as an encoding task (Nairne et al., 2008).

Secondly, to temper the above, one might consider the effects of survival processing on *involuntary* forgetting after a delay (Abel & Bäuml, 2013; Clark & Bruno, 2016; Munetsugu & Horiuchi, 2015; Parker et al., 2019). In these experiments the magnitude of forgetting that occurred in the survival condition was similar to that of the control conditions. Consequently, even though forgetting occurred following adaptive memory encoding, survival processing still produced a mnemonic advantage over the control conditions after a long (up to 48 h) delay. Based on these findings it could be argued that because both voluntary and involuntary forgetting share similar features such as cue dependency (e.g., Nørby, 2015; Sahakyan & Kelley, 2002; Tulving, 1984), then survival processing will lead to List 1 costs of the same magnitude as control tasks whilst still maintaining the advantage in relation to those tasks. Thus, like work with involuntary forgetting over time, List 1 memory is impaired in the survival condition, but still above that of the control condition.

Thirdly, information processed for its survival value might be more susceptible to intentional forgetting. This could be understood as adaptive and serving to update memory representations in-line with current goals or environmental situations (Bjork, 1978; Pastötter et al., 2017). From a survival perspective, revising memory by forgetting fitness relevant information from previous experience, and replacing with newer current details would be especially important. This is because previously germane and accessible material must be replaced since it would be maladaptive for this to constantly interfere with processing in an altered environment.

Experiment 1: method

Design

The design was a 3(Encoding condition: Survival vs. Moving vs. Pleasantness) by 2(Mid-list cue: Remember vs. Forget) completely between-subjects factorial. The dependent variables were the number of items recalled for both Lists 1 and 2 further decomposed into "remember", "know", and "guess" responses.

Participants

Participants were 132 students from Manchester Metropolitan University and were obtained from the Psychology subject pool and from opportunistic sampling.[1] Participation was voluntary and none had taken part in any similar research.

Materials & apparatus

Word lists & scenarios. The word lists and scenarios were taken from Nairne et al. (2007). A total of 24 words were used that were divided into two lists for the purpose of counterbalancing. The lists were matched on the dimensions of concreteness, familiarity, imagery, number of letters, and word frequency (the words were originally drawn from the norms of Van Overschelde et al., 2004). The scenarios were survival, moving, and pleasantness and were worded as in the Nairne et al. (2007) paper and are outlined below.

Response booklets. The response booklets contained pages to identify subject details, experimental conditions and instructions. For the rating task, a set of 12 rating scales were provided in the booklet for the participants to record their responses. For the two recall trials, separate pages contained a table with spaces to write down each word recalled. To the right side of each space were the additional response options of "remember" "know" and "guess".

A computer with software compiled for the experiment was used to present the words during the encoding phase.

Procedure

Participants were tested individually and allocated randomly to one of the six experimental conditions. Participants were asked to sit in front of a computer and were presented with the assigned encoding instructions (survival vs. moving vs. pleasantness) about rating the words. Moving and pleasantness tasks were selected as control conditions and in-line with previous work (e.g., McBride et al., 2013; Otgaar et al., 2010; Tse & Altarriba, 2010). These tasks have often been used as they are both considered to promote deep processing. This is important as any memory enhancing effects of the survival condition cannot then be concluded to arise purely as a function of depth of processing.[2]

For the survival task, participants were asked to imagine themselves stranded in the grasslands of a foreign country with no materials to aid their survival. They were told that they would thus need to find supplies of water and food and find ways to protect themselves from predators. For each word presented, participants were asked to consider their respective referents and rate the relevance of these in assisting with their survival. The moving task was described to participants as one in which they had to rate the relevance of the referents of the words in terms of assisting with the transportation of their belongings whilst moving from an old to a new house. The pleasantness task was described as one in which participants were required to rate the pleasantness of each word.

Participants were asked if they understood what was required before the start of the list presentation. At this point they were not informed about any memory task. The first list was then presented with words selected without replacement on a random basis from one of the lists. Each stimulus was presented for 4 s before changing to a blank screen. During this period the participant recorded their rating in the booklet. This was repeated for each of the 12 words.

After presentation of List 1, the instructions provided depended on whether participants had been assigned to the remember or forget conditions. For those in the remember condition, they were informed that a second list of words would be presented, and their task was to memorise the upcoming words *and* the first list for a subsequent memory test. For those in the forget condition, they were also told that a second set of words requiring memorisation would be presented. Importantly, they were told that the first list was not important for the memory test and that they should try to forget it. The nature of the test was not specified in either condition. The presentation parameters were similar to List 1 with the exception that there was no rating task and the interstimulus interval was 1 s.

After presentation of List 2, a short distractor task was administered, that required writing down the names of towns and cities in the UK for 5 min. Finally, participants were asked to recall both lists with the order of recall counterbalanced. The recall task instructions informed participants that they could recall the words from the list in any order. For each word recalled they were told to indicate their experience that accompanied recall. It was explained that recall can be experienced in several forms. The instructions defined a "remember" type recall as one that involved the conscious recall of the studied word because associated details pertaining to the word as studied came to mind. A "know" type recall was defined as one where the participant was sure that the word had appeared, but lacked any additional details pertaining to the study episode. Finally, a "guess" type recall was indicated to be one in which they felt like they were just supposing the existence of the word in the absence of any "real" memory.

These instructions were modelled on previous work (Gardiner & Richardson-Klavehn, 2000; Mickes et al., 2013). The experimenter ensured the participants fully understood the response definitions before moving onto the test. Finally, participants were thanked for their cooperation and informed that the precise details of the experiment would be disclosed to them later.

Experiment 1: results & summary

Overview of results

Separate analyses were performed for each of the DVs for each list. These took the form of a series of 3(Encoding task: Survival vs. Pleasant vs. Moving) by 2(Mid-list cue: Remember vs. Forget) completely between-subjects ANOVAs. Descriptive statistics for all measures can be seen in Table 1 and the ANOVA outcomes in Table 2. Order of list recall produced no effects and was not included in any of the analyses reported below.

List 1 memory

Overall recall. Analysis of overall recall for List 1 showed a significant main effect of encoding task (greater recall after survival processing), mid-list cue (reduced recall following the F-cue) and an interaction. Assessment of simple main effects at each level of encoding indicated lower levels of recall after the F-cue for each condition [$t(42) = 8.18$, $p < .001$, 95% CI [2.16, 3.57], Cohens $d = 2.43$, for survival, $t(42) = 1.95$, $p = .03$, 95% CI [0.03, 1.66], Cohens $d = 0.58$, for pleasantness and $t(42) = 2.54$, $p = .01$, 95% CI [0.22, 1.95], Cohens $d = 0.76$, for moving], but the magnitude of forgetting was greater for survival processing.

Remember responses. Overall recall was assessed further in terms of "remember" and "know" responses. Guess responses were at floor levels and no formal analyses were performed. The pattern of findings for "remember" responses were similar to overall recall with main effects for encoding (more "remember" responses after survival processing), fewer "remember" responses after the F-cue and an interaction. Simple main effects comparing the effect of the cue-type at each level of encoding task revealed a significant reduction in the number of "remember" responses after the F-cue for each encoding condition [$t(42) = 6.54$, $p < .001$, 95% CI [1.79, 3.57], Cohens $d = 1.95$, for survival, $t(42) = 4.35$ $p < .001$, 95% CI [0.95, 2.59], Cohens $d = 1.31$, for pleasantness and $t(42) = 2.23$, $p = .04$, 95% CI [0.09,1.73], Cohens $d = 0.66$, for moving], but the

Table 1. Experiment 1: Mean (SE) number of items recalled for each list as a function of encoding condition, response type, and mid-list cue.

	Encoding condition		
Response type & Mid-list cue	Survival	Pleasant	Moving
List 1 Recall			
Overall Recall			
R-cue	9.86 (.27)	6.14 (.33)	5.91 (.36)
F-cue	7.00 (.22)	5.32 (.26)	4.82 (.22)
Remember			
R-cue	7.55 (.31)	4.60 (.31)	4.36 (.32)
F-cue	4.95 (.25)	2.82 (.27)	3.45 (.24)
Know			
R-cue	2.18 (.28)	1.41 (.28)	1.45 (.25)
F-cue	1.95 (.23)	2.23 (.33)	1.32 (.31)
Guess			
R-cue	0.14 (.10)	0.14 (.07)	0.09 (.06)
F-cue	0.09 (.06)	0.27 (.10)	0.05 (.05)
List 2 Recall			
Overall Recall			
R-cue	8.14 (.30)	7.91 (.34)	7.82 (.36)
F-cue	8.55 (.43)	8.27 (.47)	7.68 (.30)
Remember			
R-cue	4.50 (.47)	4.09 (.54)	3.68 (.48)
F-cue	4.68 (.41)	4.05 (.55)	3.68 (.49)
Know			
R-cue	3.41 (.55)	3.73 (.62)	3.95 (.72)
F-cue	3.73 (.50)	4.05 (.54)	3.91 (.56)
Guess			
R-cue	0.23 (.11)	0.09 (.06)	0.18 (.08)
F-cue	0.14 (.07)	0.18 (.08)	0.09 (.06)
Ratings			
R-cue	2.75 (.08)	2.82 (.08)	2.88 (.14)
F-cue	2.75 (.09)	2.95 (.09)	2.94 (.10)

Table 2. Experiment 1: Summary of ANOVA results for Experiment 1.

Response Type & Source of Effect	*df*	*F*	*p*	η_p^2
List 1 Results				
Overall				
Main Effect Encoding Task	2, 126	69.85	< .001	.53
Main Effect Mid-List Cue	1, 126	47.18	< .001	.27
Interaction	2, 126	7.66	= .001	.11
Remember				
Main Effect Encoding Task	2, 126	49.17	< .001	.44
Main Effect Mid-List Cue	1, 126	56.95	< .001	.31
Interaction	2, 126	4.35	= .01	.06
Know				
Main Effect Encoding Task	2, 126	2.98	=. 06	.04
Main Effect Mid-List Cue	1, 126	0.43	= .51	.003
Interaction	2, 126	2.10	= .13	.03
List 2 Results				
Overall				
Main Effect Encoding Task	2, 126	1.28	= .28	.02
Main Effect Mid-List Cue	1, 126	0.49	= .48	.004
Interaction	2, 126	0.33	= .72	.005
Remember				
Main Effect Encoding Task	2, 126	1.71	= .19	.03
Main Effect Mid-List Cue	1, 126	0.01	= .91	< .001
Interaction	2, 126	0.03	= .97	< .001
Know				
Main Effect Encoding Task	2, 126	0.23	= .80	.004
Main Effect Mid-List Cue	1, 126	0.17	= .68	.001
Interaction	2, 126	0.06	= .94	.001
Ratings				
Main Effect Encoding Task	2, 126	1.55	= .22	.02
Main Effect Mid-List Cue	1, 126	0.65	= .42	.005
Interaction	2, 126	0.24	= .79	.004

reduction in the number of "remember" responses after the F-cue was greatest for survival processing.

Know responses. The main effect of encoding task was marginally significant, but neither the main effect of mid-list cue nor the interaction was significant.

List 2 memory

There were no main effects or interactions for List 2 variables.

Analyses of ratings data

In survival processing experiments, the rating data are analysed to assess if there are any differences in rating scores among the conditions. The mean rating for each participant was placed into a 3(Encoding Task: Survival vs. Pleasant vs. Moving) by 2(Mid-list cue: Remember vs. Forget) completely between-subjects ANOVA. The descriptive statistics and findings can be found in Table 1 and the ANOVA in Table 2. The results indicated no main effects nor an interaction.

Some research has proposed that the survival processing effect is based on the congruity between the target stimuli and the encoding task (Butler et al., 2009). Greater congruity enhances memory because the processing task and the target stimulus form an integrated unit (Schulman, 1974). Thus, if a stimulus is rated as relevant to survival, it would be predicted to bring about a memory advantage compared to one that is less relevant. This can be ascertained by assessing the correlation between the rating score and memory. Although some work has found results consistent with this, it cannot fully account for the mnemonic advantage of survival processing (Kazanas & Altarriba, 2016; Misirlisoy et al., 2019; Nairne et al., 2007). Other work has also shown survival processing effects even when there is *no* corelation between ratings and recall (e.g., Clark & Bruno, 2016), or when relevance is manipulated to be very low (e.g., Nairne & Pandeirada, 2011).

Nevertheless, the correlation between the rating scores and memory was assessed to determine if congruity effects could have contributed to the current findings. A series of Pearson's correlation tests were performed for each between-subject condition using the mean rating score for each participant and each dependent variable. For the overall number of words recalled for List 1, none of the results reached significance, all p's > .05. The highest correlation was found for the moving condition with the R-cue, $r(20) = -.33$, $p = .13$. For "remember" responses, none of the values were significant; the highest correlation was for the pleasantness condition with the R-cue, $r(20) = -.22$, $p = .33$. For "know" responses, none of the values reached traditional levels of significance with the highest correlation found in the moving condition with the R-cue, $r(20) = -.36$, $p = .10$. Consequently, the relationship between rating scores and recall cannot account for the findings of the first experiment.

Additional analyses

Non-significant findings do not provide evidence that the effects themselves are absent. Consequently, the "absence" of List 2 benefits does not mean that such benefits might not exist, merely that these were not found in the current data. One way to assess the relative degree of support for the null (vs. alternative) hypothesis is to employ Bayes factors (Rouder et al., 2012).

Use of Bayesian hypothesis testing can provide a means to assess how strongly collected data supports one model compared to another. Accordingly, it has often been proposed as an alternative to traditional frequentist hypothesis testing (e.g., Wagenmakers, 2007). It has also been proposed as a supplement to such frequentist analyses in order to enumerate the evidence in support of the null hypothesis when the outcome of such statistics is indeterminate by virtue of a non-significant finding (e.g., Dienes, 2014; Rouder et al., 2012). Use of such analyses has advantages over other approaches that make use of post-hoc power analyses and can provide accurate conclusions even for small samples (Gill, 2015; Wagenmakers et al., 2015). Consequently, Bayesian ANOVAs were conducted for List 2 recall (and the rating data) to assess the extent to which the current findings provide evidence in support of the null (vs. alternative) hypothesis.

The Bayesian analyses reported here were computed using JASP (JASP Team, 2018), and BF_{01} (Bayes factor) values reported. The Bayes factor represents the degree to which belief in the validity of the hypotheses under consideration should be updated or changed *after* data collection. The factor itself represents the ratio of the probabilities in the actual data set under the null vs. alternative hypothesis. As such, a Bayes factor of 1 indicates that the results provide equal support for the null and the alternative hypothesis. A Bayes factor of 1 and above indicate results that are more consistent with the null vs. alternate hypothesis respectively, (Morey et al., 2016). Although Bayes factors are continuous, some rules of thumb exist to aid with interpretation. For example, BF_{01} of above 3 are considered to be good evidence in favour of the null hypothesis. Values between 0.3 and 3 display more tentative support for the null hypothesis and perhaps suggest further work is required. Values below 0.3 provide evidence in favour of the alternate hypothesis with the degree of support varying with the precise value of the factor.

Using a 3(Encoding condition: Survival vs. Moving vs. Pleasantness) by 2(Mid-list cue: Remember vs. Forget) Bayesian ANOVA on overall recall of List 2 produced BF_{01} of 4.55, 4.35, and 6.67, for the main effect of encoding task, mid-list cue and the interaction respectively.

Similar ANOVAs were performed for "remember" responses and resulted in BF_{01} of 2.70, 5.26 and 7.69, for the main effect of encoding task, mid-list cue and the interaction respectively. For "know" responses, the findings were 11.11, 5.00, and 7.69, for the main effect of encoding task, mid-list cue and the interaction.

The ANOVA for the rating data resulted in BF_{01} of 3.70, 4.00, and 6.25, for the main effect of encoding task, mid-list cue and the interaction. For the correlations between the rating data and List 1 recall variables (overall recall, "remember" and "know"), all BF_{01} values were above 1 with the pattern of findings mirroring that of the frequentist results. Thus, in all instances Bayesian evidence was found weighted in favour of the null hypothesis.

Summary and discussion

For List 1 recall, Experiment 1 found a main effect of encoding task (higher after survival processing) and a main effect of mid-list cue (lower after the F-cue). Importantly, there was an interaction such that the F-cue brought about *greater* forgetting after survival processing. An additional way to gain an overall impression of the degree of forgetting is by computing forgetting as a proportion of those remembered. This is expressed as (R-cue recall – F-cue recall)/R-cue recall. As the design was between-subjects, it was not possible to calculate these on a subject-by-subject basis. Instead, using the cell means for overall recall as found in Table 1, proportional forgetting was .29 for survival, .13 for pleasantness, and .18 for moving. This demonstrates greater proportional forgetting in the survival condition.

Similar comparisons can be computed for "remember" responses and produces .34 for survival, .39 for pleasantness and .21 for moving. In this instance survival and pleasantness are similar with the reduction being greater than the moving condition. No significant effects were found for List 2 recall.

Regarding the findings of List 1 memory, two interesting points can be noted. Firstly, memory performance in the F-cue condition following survival processing was of a similar magnitude to the R-cue condition of the moving and pleasantness conditions. Thus, after survival encoding, memory was sufficiently robust to make performance equivalent to other forms of processing with intentional remember instructions (i.e., after the R-cue). Secondly, the most important outcome relates to the effects of the mid-list cue for each encoding condition. It was found that the greatest directed forgetting cost occurred after survival encoding and is thus consistent with the third of the hypotheses outlined in the introduction.

One less theoretically interesting explanation of this finding is that there was simply more information to forget following survival processing. However, this is inconsistent with the degree of proportional forgetting observed that was greater in the survival condition. In addition, other research in which survival processing produced initially superior memory, did *not* lead to a greater magnitude of forgetting (Abel & Bäuml, 2013; Clark & Bruno, 2016; Munetsugu & Horiuchi, 2015; Parker et al., 2019; Raymaekers et al., 2014). In these experiments, the degree of forgetting was similar across various encoding conditions, even though retention was higher after survival processing in the pre-delay condition. Thus, higher retention per-se in the survival condition itself does not fully explain the greater reduction in retention after the F-cue.

Another explanation of the findings arises from the context change account of directed forgetting. This states that List 1 costs are due to a change in mental context between List 1 encoding and the final recall brought about by the F-cue. It is possible that the context established by the survival scenario contains attributes that are *less* likely to overlap or be instituted at recall compared to the moving or pleasantness tasks. For example, thinking about moving or pleasantness is more commonplace and familiar than thinking about survival in the grasslands (Kazanas & Altarriba, 2016). As such, the survival scenario might be less likely to be instantiated at recall.

In addition, elements of the mental context associated with moving or pleasantness might still form part of the retrieval context because they are more commonplace. The suggestion is that the survival processing scenario is in some way more unique or less everyday compared to the other scenarios. Consequently, there is less contextual overlap between List 1 and recall for survival and thus more forgetting. If so, reinstating the encoding context should be particularly beneficial for the survival condition. To assess this, Experiment 2 manipulated mental context reinstatement after List 2 and prior to recall.

Experiment 2. Survival processing, directed forgetting and context reinstatement

It has been argued that List 1 costs are driven by a mental context change and consequently, reinstating the encoding context associated with List 1 should reduce directed forgetting costs. For example, Sahakyan and Kelley (2002) demonstrated these costs were reduced (less forgetting) when participants were asked to perform a task that required thinking back to the start of the experiment and mentally reenvisaging the point around the time of List 1 encoding. Experiment 2 implemented a reinstatement task in which half of the participants were provided with mental context reinstatement instructions prior to final recall. These instructions pertained to mentally reenvisaging survival and moving house (the pleasantness task was excluded from the second experiment).[3] It was expected that mental reinstatement would reduce List 1 costs overall but more so in the survival condition.

Experiment 2: method

Design

The design was a 2(Encoding condition: Survival vs. Moving) by 2(Mid-list cue: Remember vs. Forget) by 2

(Retrieval condition: Reinstatement vs. No reinstatement) completely between-subjects factorial. The dependent variables were the number of items recalled for both Lists 1 and 2 further decomposed into "remember", "know", and "guess" responses.

Participants

Participants were 200 students from Manchester Metropolitan University and were obtained from the Psychology subject pool and from opportunistic sampling.[4] Participation was voluntary and none had taken part in any similar research.

Materials & apparatus

Word lists & scenarios. The word lists and scenarios were the same as Experiment 1.

Response booklets. The response booklets were the same as Experiment 1 only with the addition of reinstatement instructions. These were based on those of Sahakyan and Kelley (2002) and are reproduced in the appendix.

Procedure

The procedure was the same as Experiment 1 up until the distractor task. At this point, those allocated to the reinstatement condition were paced through either a survival or moving reinstatement task. The task reminded them that a few moments ago they were asked to rate a list of words in relation to survival or moving to a new house. Particularly, to cast their mind back and think about what the rating task meant for them personally. They were asked to consider what ideas or thoughts that came to mind and where possible, try to place themselves in that same frame of mind. The instructions were delivered aurally by the experimenter according to a set script and lasted 2 min. For those in the no-reinstatement condition, a short interruption was implemented (to mimic the shift from performing the distractor task to the reinstatement task) before being allowed to continue with the distractor task for an additional 2 min to match the period for reinstatement.

Finally, participants were requested to recall List 1 and then List 2. Note that recall order was the same for all participants because it was reasoned that requesting List 2 recall first would potentially interfere with the mental context just established for List 1.

Experiment 2: results & summary

Overview of results

Separate 2(Encoding task: Survival vs. Moving) by 2(Mid-list cue: Remember vs. Forget) by 2(Retrieval condition: Reinstatement vs. No-reinstatement) completely between-subject ANOVAs were performed for Lists 1 and 2. The results analysed were overall recall and remember-know scores. The descriptive statistics and ANOVA outcomes can be found in Tables 3 and 4.

List 1 memory

Overall recall. Analysis of List 1 recall showed main effects of encoding condition (higher after survival processing), mid-list cue (lower after the F-cue) and retrieval condition (higher after reinstatement). The two-way interaction between encoding task and mid-cue was significant as was the interaction between encoding and reinstatement. The three-way interaction was not significant.

The interaction between encoding task and mid-list cue was investigated using simple main effects comparing the effect of the cue at each level of encoding. This revealed the F-cue reduced memory in both conditions, but the magnitude of the reduction was greater for the survival task, $t(98) = 6.06$, $p < .001$, 95% CI [1.63, 3.21], Cohens $d = 1.22$ and $t(98) = 1.75$, $p = .04$, 95% CI [0.10, 1.53], Cohens $d = 0.35$, respectively for the survival and moving conditions.

The interaction between encoding and retrieval conditions was assessed by simple main effects at each level of encoding condition. This was done to assess the magnitude of reinstatement effects for each encoding condition. The results revealed reinstatement to enhance memory in the moving condition, $t(98) = 5.21$, $p < .001$, 95% CI [1.19, 2.65], Cohens $d = 1.03$, but not in the survival condition $t(98) = 1.34$, $p = .18$, 95% CI [−0.30, 1.54], Cohens $d = 0.27$.

Remember responses. Analysis of "remember" responses showed main effects of mid-list cue (fewer "remember" responses after the F-cue), and retrieval condition (more "remember" responses after reinstatement). The encoding task main effect, although not significant, was reasonably close with more "remember" responses after survival encoding.

The two-way interactions for encoding task with mid-list cue and encoding task with reinstatement were both significant. The interaction between reinstatement and mid-list cue was not significant, nor was the three-way interaction.

The interaction between encoding task and mid-cue was investigated with simple main effects comparing the effect of the cue at each level of encoding. This revealed the F-cue to reduce the number of "remember" responses in the survival condition only, $t(98) = 4.12$, $< .001$, 95% CI [1.00, 2.84], Cohens $d = 0.82$, and, $t(98) = 0.21$, $p = .83$, 95% CI [−1.04, 0.84], Cohens $d = 0.04$, respectively for the survival and moving conditions.

The interaction between encoding and retrieval conditions was assessed by simple main effects at each level of encoding condition. This revealed reinstatement to enhance "remember" responses in the moving condition [$t(98) = 5.10$, $p < .001$, 95% CI [1.31, 2.97], Cohens $d = 1.01$], but not in the survival condition [$t(98) = 1.04$, $p = .30$, 95% CI [−0.47, 1.51], Cohens $d = 0.21$].

Table 3. Experiment 2: Mean (SE) number of items recalled for each list as a function of encoding condition, response type, retrieval condition and mid-list cue.

	Encoding condition			
	Survival		Moving	
Response type & Mid-list cue	Reinstatement	No-reinstatement	Reinstatement	No-reinstatement
List 1 Recall				
Overall Recall				
R-cue	8.32 (.41)	6.96 (.36)	7.16 (.40)	5.12 (.38)
F-cue	5.16 (.39)	5.28 (.39)	6.32 (.38)	4.52 (.28)
Remember				
R-cue	6.64 (.47)	5.52 (.43)	5.88 (.38)	3.40 (.50)
F-cue	4.12 (.46)	4.20 (.50)	5.44 (.42)	3.64 (.37)
Know				
R-cue	1.36 (.29)	0.92 (.24)	1.04 (.28)	1.40 (.39)
F-cue	0.84 (.26)	0.88 (.28)	0.76 (.23)	0.68 (.30)
Guess				
R-cue	0.32 (.13)	0.52 (.19)	0.24 (.09)	0.32 (.10)
F-cue	0.20 (.08)	0.20 (.10)	0.12 (.07)	0.20 (.13)
List 2 Recall				
Overall Recall				
R-cue	6.04 (.49)	6.32 (.49)	5.84 (.39)	5.64 (.52)
F-cue	6.04 (.57)	7.60 (.40)	6.88 (.48)	6.88 (.49)
Remember				
R-cue	4.40 (.55)	5.00 (.62)	4.80 (.40)	3.88 (.64)
F-cue	4.76 (.63)	5.72 (.59)	5.32 (.40)	4.84 (.65)
Know				
R-cue	1.16 (.41)	0.88 (.28)	0.72 (.22)	1.44 (.42)
F-cue	1.04 (.45)	1.48 (.44)	1.20 (.39)	1.60 (.39)
Guess				
R-cue	0.48 (.15)	0.44 (.16)	0.32 (.17)	0.32 (.13)
F-cue	0.24 (.09)	0.44 (.14)	0.36 (.21)	0.44 (.21)
Ratings				
R-cue	2.74 (.15)	2.61 (.13)	2.67 (.13)	2.52 (.13)
F-cue	2.68 (.13)	2.64 (.13)	2.44 (.11)	2.69 (.14)

Know responses. There were no significant effects for "know" responses, albeit the main effect for mid-list cue was close to conventional levels of significance and showing fewer "know" responses after the F-cue. Like Experiment 1, guess responses were at floor levels and no formal analyses were performed.

List 2 memory

Analyses of List 2 recall revealed only a main effect of mid-list cue. This showed greater recall after the F-cue irrespective of encoding or retrieval condition. The interaction between encoding and retrieval conditions was marginal for "remember" responses; observation of the means collapsed across mid-list cue indicated that reinstatement increased the number of such responses for the moving condition but not the survival condition. Know responses produced no main effects or interactions.

Analyses of ratings data

Like Experiment 1, rating data were assessed to see if there were any differences in scores among the conditions. The mean rating score for each participant was placed into a 2 (Encoding task: Survival vs. Moving) by 2(Mid-list cue: Remember vs. Forget) by 2(Retrieval condition: Reinstatement vs. No-reinstatement) completely between-subjects ANOVA. The descriptive statistics and findings can be found in Tables 3 and 4. The results indicated no significant main effects or interactions.

Like the first experiment, the correlations between the rating scores and memory performance were calculated for each of the between-subject conditions. For the overall number of words recalled for List 1, none of the results reached significance with the highest correlation in the moving condition with the R-cue and context reinstatement, $r(23) = .34$, $p = .09$. For "remember" responses, the only correlation to reach significance was for survival encoding with the R-cue and context reinstatement, $r(23) = .48$, $p = .02$. For "know" responses, none of the results were significant with the highest correlation in the survival condition with the R-cue and context reinstatement, $r(23) = -.37$, $p = .07$.

Given so few correlations reached significance, it is unlikely that the pattern of findings found in Experiment 2 can be explained based purely on congruity effects.

Additional analyses

As in Experiment 1, Bayesian analyses were conducted to further assess the null findings from the frequentist results. The aim was to evaluate the Bayesian evidence in favour (or against) the null model of the current data. Values of BF_{01} greater than one indicates support for the null model in varying degrees depending on the size of the Bayes factor.

Table 4. Experiment 2: Summary of ANOVA results for Experiment 2.

Response type & Source of effect	*df*	*F*	*p*	η_p^2
List 1 Results				
Overall				
Main Effect Encoding Task	1, 192	5.91	= .02	.03
Main Effect Mid-List Cue	1, 192	34.47	< .001	.15
Main Effect Retrieval Condition	1, 192	22.56	< .001	.11
Interaction (encoding X mid-list cue)	1, 192	10.10	= .002	.05
Interaction (encoding X retrieval)	1, 192	5.91	= .02	.03
Interaction (mid-list cue X retrieval)	1, 192	2.59	= .11	.01
Interaction (three way)	1, 192	1.34	= .25	.007
Remember				
Main Effect Encoding Task	1, 192	2.86	= .09	.02
Main Effect Mid-List Cue	1, 192	10.38	= .001	.05
Main Effect Retrieval Condition	1, 192	18.00	< .001	.09
Interaction (encoding X mid-list cue)	1, 192	8.43	= .004	.04
Interaction (encoding X retrieval)	1, 192	6.68	= .01	.03
Interaction (mid-list cue X retrieval)	1, 192	2.25	= .14	.01
Interaction (three way)	1, 192	0.17	= .68	.001
Know				
Main Effect Encoding Task	1, 192	0.02	= .88	< .001
Main Effect Mid-List Cue	1, 192	3.68	= .06	.02
Main Effect Retrieval Condition	1, 192	0.02	= .88	< .001
Interaction (encoding X mid-list cue)	1, 192	0.29	= .59	.002
Interaction (encoding X retrieval)	1, 192	0.70	= .40	.004
Interaction (mid-list cue X retrieval)	1, 192	0.002	= .96	< .001
Interaction (three way)	1, 192	1.28	= .26	.007
List 2 Results				
Overall				
Main Effect Encoding Task	1, 192	0.31	= .58	.002
Main Effect Mid-List Cue	1, 192	6.79	= .01	.03
Main Effect Retrieval Condition	1, 192	1.44	= .23	.007
Interaction (encoding X mid-list cue)	1, 192	0.54	= .46	.003
Interaction (encoding X retrieval)	1, 192	2.23	= .14	.01
Interaction (mid-list cue X retrieval)	1, 192	1.17	= .28	.006
Interaction (three way)	1, 192	0.63	= .43	.003
Remember				
Main Effect Encoding Task	1, 192	0.42	= .52	.002
Main Effect Mid-List Cue	1, 192	2.54	= .11	.013
Main Effect Retrieval Condition	1, 192	0.01	= .92	< .001
Interaction (encoding X mid-list cue)	1, 192	0.06	= .80	< .001
Interaction (encoding X retrieval)	1, 192	3.39	= .07	.02
Interaction (mid-list cue X retrieval)	1, 192	0.25	= .62	.001
Interaction (three way)	1, 192	0.01	= .96	< .001
Know				
Main Effect Encoding Task	1, 192	0.14	= .71	.001
Main Effect Mid-List Cue	1, 192	1.07	= .30	.006
Main Effect Retrieval Condition	1, 192	1.39	= .24	.007
Interaction (encoding X mid-list cue)	1, 192	0.02	= .88	< .001
Interaction (encoding X retrieval)	1, 192	0.78	= .38	.004
Interaction (mid-list cue X retrieval)	1, 192	0.14	= .71	.001
Interaction (three way)	1, 192	0.92	= .34	.005
Ratings				
Main Effect Encoding Task	1, 192	0.80	= .37	.004
Main Effect Mid-List Cue	1, 192	0.07	= .79	< .001
Main Effect Retrieval Condition	1, 192	0.04	= .84	< .001
Interaction (encoding X mid-list cue)	1, 192	0.01	= .95	< .001
Interaction (encoding X retrieval)	1, 192	0.51	= .48	.003
Interaction (mid-list cue X retrieval)	1, 192	1.67	= .20	.009
Interaction (three way)	1, 192	0.65	= .42	.003

For List 1 overall recall the BF_{01} values were as follows: mid-list cue by reinstatement interaction = 1.59, and the encoding task by mid-list cue by reinstatement interaction = 2.08.

For List 1 "remember" responses the Bayes factors were as follows: encoding task = 2.13, mid-list cue by reinstatement interaction = 5.56, and the encoding task by mid-list cue by reinstatement interaction = 3.45.

For List 1 "know" responses the Bayes factors were as follows: encoding task = 6.67, mid-list cue = 1.25, reinstatement = 6.67, the encoding task by mid-list cue interaction = 3.70, the encoding task by reinstatement interaction = 3.03, the mid-list cue by reinstatement interaction = 5.26, and the encoding task by mid-list cue by reinstatement interaction = 2.08.

For List 2 overall recall the Bayes factors were as follows: encoding task = 5.56, reinstatement = 3.03, the encoding task by reinstatement interaction = 1.72, the mid-list cue by reinstatement interaction = 3.03, the encoding task by mid-list cue interaction = 4.00, and the encoding task by mid-list cue by reinstatement interaction = 3.13.

For List 2 "remember" responses the Bayes factors were as follows: encoding task = 5.26, mid-list cue = 1.96, reinstatement = 6.67, the encoding task by mid-list cue interaction = 4.55, the encoding task by reinstatement interaction = 1.16, the mid-list cue by reinstatement interaction = 4.35, and the encoding task by mid-list cue by reinstatement interaction = 3.85.

For List 2 "know" responses the Bayes factors were as follows: encoding task = 6.25, mid-list cue = 4.00, reinstatement = 3.33, the encoding task by mid-list cue interaction = 5.00, the encoding task by reinstatement interaction = 3.57, the mid-list cue by reinstatement interaction = 4.54, and the encoding task by mid-list cue by reinstatement interaction = 2.27.

The ANOVAs for the ratings scores produced the following Bayes factors: encoding task = 4.54, mid-list cue = 6.25, reinstatement = 6.25, the encoding task by mid-list cue interaction = 5.00, the encoding task by reinstatement interaction = 3.70, the mid-list cue by reinstatement interaction = 2.33, and the encoding task by mid-list cue by reinstatement interaction = 2.44.

The Bayesian correlations between the rating scores and memory produced only two results moderately in favour of the alternate hypothesis. The correlations were positive for "remember" and negative for "know" responses in the survival condition with the R-cue and reinstatement, $BF_{01} = 0.26$, and $BF_{01} = 0.81$ respectively.

Thus, the findings from the Bayesian analyses produce results (BF_{01}) above 1 and indicate the data are more consistent with the null model. Of course, the degree to which support for the null hypothesis was found varied across the analyses with some being more equivocal (e.g., the effect of the mid-list cue on "know" responses).

Summary

Experiment 2 found similar effects to the first experiment for List 1 recall. Namely, an overall survival processing advantage, reduced memory following the cue to forget and an interaction between encoding task and mid-list cue. Like the first experiment, the proportion of forgetting as a function of items in the R-cue condition was calculated using cell means. This produced values of .32 and .12 for the survival and moving conditions respectively. For "remember" responses, proportional forgetting was .31 for survival processing and .02 for the moving condition.

Retrieval condition produced a significant main effect (greater recall following mental reinstatement) and an interaction between encoding and retrieval conditions. However, contrary to expectations, List 1 costs were not reduced to a greater extent in the survival condition. Rather, reinstatement reduced List 1 costs more in the moving condition. That is, mental reinstatement enhanced List 1 recall for the moving condition only.

Greater List 2 memory following the F-cue (the benefit of directed forgetting) was found as a main effect only, and the mid-list cue did not interact with either encoding or retrieval conditions.

General discussion

General consideration of the current findings

Two experiments assessed the effects of survival processing on the ability to voluntarily forget information. Regarding List 1 memory, the key findings were: (i) in both experiments an interaction was found such that the F-cue brought about greater forgetting after survival processing, (ii) this interaction was found largely in "remember" responses. The influence of survival processing on "remember" responses is similar to that obtained on tests of recognition memory (e.g., Munetsugu & Horiuchi, 2015; Parker et al., 2019). To our knowledge, this is the first demonstration of this with free-recall. Regarding List 2 memory, directed forgetting benefits (enhanced memory for the second list following the F-cue) were found only in the second experiment. This occurred as a main effect only and did not interact with either the encoding or retrieval conditions.

With respect to the possible outcomes noted in the introduction, the results are consistent with the hypothesis that information processed for its survival value is more susceptible to intentional forgetting. This is examined below from the perspectives of theoretical accounts of directed forgetting and survival processing.

Explaining the current findings in terms of accounts of directed forgetting

Although the aims of the current studies were not to adjudicate between theories of directed forgetting, the findings can be examined from the perspective of these accounts and in part speak to them. The most important and novel finding from both experiments was that survival processing led to greater List 1 costs following presentation of the F-cue even though the typical survival advantage was obtained when instructed to remember.

A possible theoretical explanation of these findings can be found in the context change account that motivated Experiment 2. This describes forgetting as due to a shift in mental context between encoding of List 1 and retrieval following List 2. If costs are indeed due to an alteration in mental context, then reinstating the List 1 context at retrieval should reduce the magnitude of forgetting. This was predicted to be greater for the survival condition as it was argued that survival processing could be more unusual or less familiar compared to the comparison tasks (e.g., Kazanas & Altarriba, 2016). If so, then a survival-based mental context might be *less* likely to be reengaged during the memory test compared to the other tasks. However, Experiment 2 demonstrated that this was not the case. Despite this, the Bayesian analyses of the three-way interaction demonstrated that although the evidence was largely in favour of the null model, this was only by a relatively small degree of 2–1 ($BF_{01} = 2.08$).

Notwithstanding this, an interesting finding was that context reinstatement led to a numerical increase in overall recall for List 1 items *except* for the survival/forget condition.[5] To speculate, it could be that mental reinstatement might not improve memory for information processed for its survival value. The context reinstatement account of List 1 costs makes no particular provision for why this might be the case. To explain this, perhaps reinstatement is insufficient to improve memory when a survival advantage could be gained by preventing the retrieval of that information. For example, from an evolutionary perspective it would be maladaptive to constantly recall where resources *were* located but have since shifted. Although plausible, caution needs to be exercised for this finding until further work can more conclusively demonstrate an interaction between reinstatement, encoding and cues to forget.

An alternative explanation of directed forgetting costs relies on the notion that List 1 becomes inhibited following the presentation of the F-cue (e.g., Anderson, 2005; Bjork, 1989; Conway et al., 2000; Geiselman et al., 1983). Given that survival processing strengthens memory, then presumably this would predict smaller List 1 costs after survival encoding as such memories are more difficult to inhibit. However, under certain condition, greater inhibition could be adaptive and serve the purpose of keeping memory representations updated and in-line with current processing objectives or environmental situations (Bjork, 1978; Pastötter et al., 2017).

Regarding inhibition, it has been hypothesised that motivated forgetting brings about greater forgetting for "remember" (vs. "know") responses (Sadeh et al., 2014). The current findings were consistent with this prediction. The reason is that pattern separation is more effective for those memories that are more detailed (recollected or "remembered") as this improves the ability to distinguish between relevant and interfering items (Sadeh et al., 2014).

Thus, from a survival perspective, there is a greater need to inhibit what was once highly accessible fitness-relevant information. This would assist with reducing interference from outdated information whose activation could prove to be especially maladaptive in ever changing environments. Of course, this notion requires further exploration and other measures of the extent to which fitness-relevant information is inhibited.

Finding greater forgetting under tasks that improve memory may seem somewhat counterintuitive, but it is not without some precedent. For example, Sahakyan et al. (2008) (Experiment 3) found that although memory following an R-cue was enhanced by spacing (vs. massing) of half the items in each list, this also brought about greater List 1 costs after the F-cue. Thus, like the current experiments, *more forgetting* occurred following a manipulation that *enhanced memory* overall. Sahakyan et al. (2008) explained their findings by reference to the idea that spacing (vs. massing) leads to the storage of additional context information. To the extent the cue to forget produces a context change, then memory for spaced (vs. massed) items should be reduced by a greater magnitude as context is used initially in free-recall to aid the recovery of items. However, this account has some difficulties in explaining the findings reported here as the items were presented once only and reinstating context did not improve memory in the survival/forget condition.

Before moving on, it is worthwhile noting that the benefits of directed forgetting (higher List 2 recall following the F-cue) were not found in Experiment 1, while the second experiment revealed an overall enhancement of List 2 memory after forgetting (main effect of mid-list cue). The absence of benefits is incompatible with single-factor accounts of list-method directed forgetting. According to these, both the costs and the benefits should arise in conjunction with one another; lower List 1 recall (costs) should reduce the amount of proactive interference on List 2 and thus increase recall of the latter (benefits). However, this is not always found, and dual-factor accounts describe costs and benefits as arising from different mechanisms. For example, costs are explained as the result of inhibition (Pastötter & Bäuml, 2010) or context changes (Sahakyan & Delaney, 2003), with benefits accruing from encoding strategy changes (Sahakyan & Delaney, 2003) or the resetting of encoding operations (Pastötter et al., 2017).

As Experiment 1 did not reveal a List 2 benefit, one explanation is that participants did not change their encoding strategy or reset encoding operations. Instead, they could have continued to make use of the same encoding task from List 1 resulting in encoding "spill-over" effects. This refers to situations in which the type of encoding used for one set of items is later applied to another set of items (e.g., Huff et al., 2021). However, if this were true, then participants would likely to have continued to make use of the same encoding strategy as for List 1 and a survival advantage would be obtained for List 2 recall. That this was not found in either experiment suggests that "spill-over" effects from List 1 did not play a significant role in the processing of List 2 items. Nevertheless, a shift in encoding strategy presumably did take place due to the change from incidental to intentional learning instructions for List 2. However, regardless of the precise details of any changes in processing, the result was similar levels of List 2 memory irrespective of the prior encoding task and reinstatement (Experiment 2) or encoding task and cue (Experiment 1).

Explaining the current findings in terms of accounts of survival processing

Much research in survival processing has examined possible *proximal* explanations for the effect. These attempt to account for how adaptive advantages occur in terms of cognitive or physiological mechanisms (Nairne & Pandeirada, 2016). One of the most promising is that based on elaboration or richness of encoding (Kroneisen et al., 2013). From this perspective, survival processing promotes a greater degree of elaboration during encoding compared to control scenarios. This in turn creates more retrieval cues and thus improves memory. This would explain enhanced overall recall of List 1 items and "remember" responses after survival processing, especially following the R-cue, as elaborative processing increases detailed recollection (Gardiner et al., 1994). However, it is difficult to see how it could also account for greater forgetting after the F-cue; if more retrieval cues are created with survival processing then why is that material easier to forget?

One possibility is that elaboration involves the generation of multiple contextual cues with the cue to forget producing a context change and thus greater forgetting. The difficulty with this is that mental contextual reinstatement did not reduce the greater magnitude of forgetting after survival encoding. Another is that the survival related cues generated in the reinstatement phase did not match those from encoding; resulting in a lack of encoding-retrieval overlap and thus impaired memory. This is difficult to evaluate based on the current findings, as any cognitive responses generated during encoding (and that may later act as retrieval cues) were not collected. Some work has made use of a thought generation procedure (e.g., Nairne et al., 2019; Röer et al., 2013), but this was done only during encoding. Consequently, examining the overlap between encoding and retrieval represents a promising way to further survival processing research and assess the importance of the contextual reinstatement account of greater List 1 costs following such encoding.

Other proximal explanations of the survival processing effect that have gained some traction and empirical support include planning (Klein et al., 2011), and self-referential processing (Klein, 2012). It is difficult to see how the current findings could be integrated *specifically* with these. However, to the extent that both planning and selfreferencing also require some degree of elaboration during encoding (Kazanas & Altarriba, 2016), then perhaps these can accommodate the present findings at least in a general manner. Thus, from an adaptationist perspective, outdated memories for fitness relevant details need to be made less accessible in order to prevent interference with new learning that has direct survival implications.

Limitations & future work

Although some possible future work was noted above, additional points are considered here that could further elucidate the current findings and extend these to other paradigms.

Remembering and forgetting are interlinked with the type of forgetting being dependent on the processes involved in initial acquisition (Sadeh et al., 2014). In relation to directed forgetting, it has been reported that subjects employ a range of strategies to forget the first list (Gamboa et al., 2017; Sahakyan et al., 2008). Useful in future work would be the assessment of the stratagems reported by subjects in their attempts to forget and how this might vary as a function of prior encoding tasks. For example, it could be that survival processing leads to qualitatively different or more successful strategies compared to other conditions. Speculatively, some strategies might be more adaptive and subsequent research could consider not simply survival-related encoding, but survival-related forgetting.

The current experiments made use of list-method directed forgetting. Directed forgetting has also been studied using the item-method in which cues to remember or forget are presented after each item. It remains an open question whether the findings obtained here generalise to this procedure, as list and item-methods have shown numerous differences (Basden & Basden, 1998). It would be of interest to see if survival encoding is more or less resistant to intentional forgetting when cues are presented after each item. Often, differences between the influence of R and F-cues in the item-method are explained by encoding related factors, such as selective rehearsal and segregation (MacLeod, 1998). This differs from the list method where retrieval factors are considered to be more important (Basden & Basden, 1998).

In the present experiments, List 2 instructions always emphasised intentional learning. This was because of the wish to keep the learning of the second list similar across all conditions. It is possible that the findings reported here are thus limited to such conditions and may vary if List 2 learning is incidental or uses the same instructions as for List 1. Future work should therefore consider aspects of the procedure in which the type of encoding instructions for List 2 is systematically manipulated. For example, what would be the effect on List 1 memory if List 2 was encoding under the same (vs. different) encoding instructions?

Summary and conclusions

Two experiments examined the effects of survival processing on list-method directed forgetting. Findings revealed fitness-relevant memories to be flexible and responsive to changing processing goals such that survival processing both increased remembering and the degree of forgetting. This pattern of results is consistent with the notion that certain types of encoding and forgetting processes can be considered from an adaptationist perspective. Survival encoding can promote memory when such remembering is goal relevant and conversely, reduce memory when processing priorities change, and mental representations needs to be updated. Increased forgetting with survival processing following the F-cue can be explained as adaptive as survival relevant memories need to be current and outdated memories prevented from interfering with these as inaccurate representations could come at a severe cost. Preventing interference can be achieved by inhibitory processing or shifts in mental context. Although firm support for the latter was not found, further work needs to be undertaken to establish the mechanisms for the current findings.

Notes

1. Sample sizes were determined by a consideration of both past research and size calculations using G*Power 3.1 (Faul et al., 2009). For directed forgetting, previous meta-analyses indicated a moderate to large effect size for the directed forgetting effect (Pastötter et al., 2012; Titz, & Verhaeghen, 2010). Using η_p^2 = .08, α = .05, *df* numerator = 1, for 80% power, the estimated total sample size was 90. Survival processing has also revealed a moderate to large effect size in between-subject groups (Scofield et al., 2018). Using similar parameters to directed forgetting, (with adjusted df for the numerator, 2 rather than 1 as there were three groups) η_p^2 =.08, α = .05, *df* numerator = 2, for 80% power, the estimated total sample size was 111. The final sample size chosen was 132.
2. In other work, only one control condition has been employed (e.g., Clark & Bruno, 2016; Meyers et al., 2020; Stillman et al., 2014). Typically, no rationale has been given for selecting one task (e.g., pleasantness) as opposed to the other (e.g., moving). Beyond this, other work has made use of a variety of encoding control tasks such as ratings of self-relevance (e.g., Dewhurst, Anderson, Grace, & Boland, 2017), or zombie attacks, (e.g., Bonin et al., 2019). Use of these (and maybe even relevance) as control tasks remain for future work that combines adaptive memory processing and directed forgetting.
3. The pleasantness task was not included in Experiment 2 as this and the moving condition produced equivalent results in the first study. Other work has also made use of just one comparison task (e.g., Clark & Bruno, 2016; Nairne et al., 2017).
4. Specifying the effect size for a possible three-way interaction was difficult given the lack of any prior work. Instead sample size determination was assessed in two ways. Firstly, given the possibility of a higher order interaction, the intention was to perform two separate simple interaction effects analyses (one at each level of reinstatement). Thus, we wished to possess an adequate sample size for this. To achieve this, the effect size obtained for the two-way interaction from Experiment 1 (η_p^2 = .11) was selected as a basis. However, it

was considered that this may be an overestimation and so a smaller effect size of η_p^2 = .08 was chosen. Thus for η_p^2 = .08, α = .05, *df* numerator = 1, for 80% power, the estimated total sample size for a 2 × 2 simple interaction effect was 90. Thus, for two simple interaction effects this was doubled to give 180. Secondly, a sample size calculation was also performed for a 2 by 2 by 2 interaction. To do this, MorePower 6.0 (Campbell, & Thompson, 2012) was used as this enables sample size and power analyses for higher order interactions. A three-way between-subjects design was specified, and the sample size required to detect a three-way interaction was computed for 80% power and α = .05. The two-way interaction effect size was used as a basis for this. However, it was likely that this would be an overestimation and so a more conservative value was used of η_p^2 = .04 (midway between a small and moderate effect size). This produced an estimate of 192 in total. The final sample size chosen was 200.

5. Although the three-way interaction was not significant, this point was highlighted during the first round of reviews and we mention it here by virtue of its possible significance to the context change account of directed forgetting.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Survival reinstatement task

Please take a minute to recall what you were doing immediately prior to experiment and where you came from. [Pause.]

At the start of this experiment you were asked to rate a list of words according to their relevance to survival in the grasslands. Please try to cast your mind back to that rating task and think about what that task actually involved for you personally.

Try to consider what came to mind including any thoughts, or ideas. Attempt to reflect on whether you thought of any images or whether you felt any emotions or feelings. Close your eyes if you feel this may help you.

Above all, I would like you to try and place yourself in the same frame of mind that you were in when you made sense of the rating task and what survival in the grasslands meant to you earlier in this study.

Moving reinstatement task

Please take a minute to recall and write down in brief phrases or words what you were doing immediately prior to experiment and where you came from. [Pause.]

At the start of this experiment you were asked to rate a list of words according to their relevance to moving house to a foreign land. Please try to cast your mind back to that rating task and think about what that task actually involved for you personally.

Try to consider what came to mind including any thoughts, or ideas. Attempt to reflect on whether you thought of any images or whether you felt any emotions or feelings. Close your eyes if you feel this may help you.

Above all, I would like you to try and place yourself in the same frame of mind that you were in when you made sense of the rating task and what moving to a foreign land meant to you earlier in this study.