Otgaar, H., Howe, M. L., Smeets, T. & Garner, S. R. (2014). Developmental trends in adaptive memory. Memory, 22(1), pp. 103-117. doi: 10.1080/09658211.2013.781653

Developmental Trends in Adaptive Memory

Henry Otgaar[1], Mark L. Howe[2], Tom Smeets[1], and Sarah R. Garner[3]

[1]Maastricht University, The Netherlands

[2]City University London, UK

[3]Lancaster University, UK

Word count (main text without references): 8294

IN PRESS: *Memory*

Correspondence to Mark L. Howe, Department of Psychology, City University London,
Northampton Square, London EC1V 0HB UK. E-mail address: drmarkl.howe@gmail.com

Abstract

Recent studies have revealed that memory is enhanced when information is processed for fitness-related purposes. The main objective of the current experiments was to test developmental trends in the evolutionary foundation of memory using different types of stimuli and paradigms. In Experiment 1, 11-year-olds and adults were presented with neutral, negative, and survival-related DRM word lists. We found a memory benefit for the survival-related words and showed that false memories were more likely to be elicited for the survival-related word lists than for the other lists. Experiment 2 examined developmental trends in the survival processing paradigm using neutral, negative, and survival-related pictures. A survival processing advantage was found for survival-related pictures in adults, for negative pictures in 11/12-year-olds, and for neutral pictures in 7/8-year-olds. In Experiment 3, 11/12-year-olds and adults had to imagine the standard survival scenario or an adapted survival condition (or pleasantness condition) that was designed to reduce the possibilities for elaborative processing. We found superior memory retention for both survival scenarios in children and adults. Collectively, our results evidently show that the survival processing advantage is developmentally invariant and that certain proximate mechanisms (elaboration and distinctiveness) underlie these developmental trends.

Keywords: Adaptive memory, proximate mechanisms, false memory, memory, development

Developmental Trends in Adaptive Memory

The argument that our memory systems are shaped because of selection pressures present in the ancestral past and associated with survival and reproductive success is not new and is advocated by many memory scholars (e.g., Anderson, 1989; Klein, Cosmides, Tooby, & Chance, 2002). This view implies that remnants of these selection pressures may have left notable imprints in the operating characteristics of memory and that as a result, memory is especially engineered to encode, store, and retrieve information relevant for survival. Interestingly, such a view about memory can easily be placed into an empirical program that does not fall prey to the "just-so" and "Panglossian" critiques often enshrined within the tenets of evolutionary psychology (Gould & Lewontin, 1979). Indeed, this interpretation about the genesis of memory is ripe for a priori predictions regarding the evolutionary constraints of memory.

A paradigm that has engendered specific predictions about adaptive memory is the survival-processing paradigm. Indeed, recent interest in the evolution of memory has been fuelled primarily as the result of findings from this paradigm, ones that show that memory performance is superior when processing has focused on the fitness-relevance of the to-be-remembered information. For example, in the first study of this sort, Nairne, Pandeirada, and Thompson (2007) had participants take part in an incidental memory paradigm in which they were instructed to imagine different ancestrally-relevant situations and rate a set of unrelated words for their relevance to survival in this situation. Specifically, some participants had to imagine being stranded on the grasslands of a foreign land without any food and drinks and in potential threat of predators. Other participants had to imagine that they had to move to a foreign land or had to indicate how pleasant they experienced the words. After the imagination instruction and a short filler task, participants received a surprise memory task. Nairne and colleagues showed that memory retention was highest for the group that had to process survival-related information. This effect has also been dubbed the survival processing advantage.

Since the advent of this study, numerous replication studies on the survival processing advantage have been conducted. Basically, it has been shown that the survival processing advantage is a robust phenomenon under a wide variety of conditions. To review some studies, the survival processing advantage persisted even when control conditions were matched on arousal, novelty, and media exposure (Kang, McDermott, & Cohen, 2008), schematic processing (Weinstein, Bugg, & Roediger, 2008), when control conditions were used that are known to boost memory retention (Nairne, Pandeirada, & Thompson, 2008), and when visual stimuli (i.e., pictures) were used (Otgaar, Smeets, & van Bergen, 2010). Furthermore, the effect remained intact in recall and recognition tests and for between- and within-subjects designs (e.g., Nairne et al., 2007). Importantly, while most of these studies have used the *incidental* survival memory paradigm to analyze the evolutionary foundations of memory, studies have also shown that memory performance is sensitive for survival-relevant information in *intentional* memory tasks (Howe & Derbish, 2010; Otgaar, Howe, Smeets, Raymaekers, & van Beers, in press). Collectively, studies have confirmed that memory prefers the processing of information related to survival value (for a review see Nairne & Pandeirada, 2010). Furthermore, it has been shown that not only survival processing results in mnemonic advantages, also survival information leads to similar benefits (Howe & Derbish, 2010)

Besides the abundance of successful replications, studies have also revealed certain boundary conditions of the survival processing advantage. For example, Savine, Scullin, and Roediger (2011) demonstrated that when faces were employed as target stimuli, the survival processing effect vanished. Seamon and colleagues (2012) examined whether the survival recall effect could be generalized to story memory, yet failed to obtain any evidence for it. Otgaar and

Smeets (2010) showed that survival processing also increases false memory rates and that when net accuracy scores (true/true + false) are computed, accuracy is actually lower in survival-processing conditions than in other relevant control conditions (see also Howe & Derbish, 2010; Otgaar et al., in press). Furthermore, it seems that the survival processing advantage is only limited to explicit memory tests and does not emerge in implicit memory tests (Tse & Altaribba, 2010).

There are also studies that have included several control conditions that made the survival processing advantage disappear. Soderstrom and McCabe (2011) compared the survival group with a group that had to imagine being attacked by zombies and found that no survival recall effect emerged. Howe and Derbish (in press) varied ancestral relevance (survival in the grasslands versus survival on an alien planet) and found that survival-processing effects were identical regardless (i.e., no recall advantage) of the ancestral nature of the processing task. Finally, Klein, Robertson, and Dalton (2011) reasoned that a critical element of survival is to successfully plan the future. They compared the original survival instruction with an instruction in which participants had to plan a camping trip. Intriguingly, their results showed that no survival processing advantage was present and that even the planning group outperformed the survival group in terms of memory performance.

Some of the just-mentioned findings could be captured under the guise of “ultimate” explanations of adaptive memory (e.g., Nairne et al., 2008). That is, these studies have focused on the evolutionary function of memory suggesting that reproductive success enhances when humans are better able to recollect survival-related information. However, to completely comprehend the survival processing advantage, one should also examine the exact underpinnings – the proximate mechanisms – of this adaptive memory effect (Scott-Phillips, Dickens, & West, 2011). Specifically, ultimate explanations refer to *why* a certain trait or behavior developed and which fitness consequences such a trait or behavior entails. Regarding the survival processing advantage, Nairne et al. (2007) were the first explicating the ultimate role of memory by asking why memory should show a preference to survival-relevant information. So, the ultimate explanation concerning the evolution of memory is that it is provides priority to fitness-relevant information. Proximate explanations are involved in *how* a certain trait or behavior evolved and which mechanisms underlie that trait or behavior. Thus, proximate explanations build on processes that have emerged to achieve the evolutionary purpose of memory (Howe & Otgaar, 2013).

In the first paper on adaptive memory, Nairne and colleagues (2007) argued that it is unlikely that the survival processing advantage maps on a specific cognitive "survival" adaptation or survival module specialized to process fitness-relevant information. Instead, they reasoned that different sets of mechanisms have been developed that process for example food and predators and that these mechanisms in concert underlie the survival processing advantage. However, we argue that the survival processing advantage is more likely to be the result of mechanisms unrelated to the concept of survival, but which have an effect on memory performance. Interestingly, recent studies shed light on possible proximate mechanisms underlying the survival processing advantage.

For example, Burns, Burns, and Hwang (2011) argued that memory preferentially retains information critical for survival because the standard survival instruction loads on both item-specific and relational processing that jointly maximize memory performance (also see Howe & Derbish, in press). Indeed, in the Burns et al. study, they showed that when the survival instruction was compared to conditions that increase both types of processing, no survival recall effect was found. In a related study, Kroneisen and Erdfelder (2011) argued that the richness and distinctiveness of the survival scenario causes participants to create more elaborate memory traces and thereby also more retrieval opportunities (see also Howe & Derbish, in press). In their study, they contrasted the original survival instruction with an instruction in which there was a decreased probability to engage in elaborative processing (i.e., participants received a survival instruction but it focused only on one problem (finding water) instead of more problems). They showed in two experiments using both a between- and within-subjects design that with this method, the original survival group did not yield superior memory retention.

Of particular relevance for the adaptive memory field is the question of whether memory is also tuned for survival-relevant information early in ontogeny. The first study that addressed this issue showed that 8- and 12-year-olds also displayed a memory benefit for information processed for survival relevance (Otgaar & Smeets, 2010). This effect has also been demonstrated in 4- and 10-year-old children (Aslan & Bauml, 2012). Moreover, 12-year-old children also showed a survival memory benefit in intentional memory tasks (Otgaar et al., in press). These studies suggest that even early in development, memory is especially sensitive for processing and retaining fitness-relevant information.

The ontological question about the onset of fitness-related mnemonic advantages is relevant because one might argue that for memory to be truly adaptive, its operating evolutionary characteristics should also be notable in children. Indeed, many behaviors that are considered to be adaptive are present early in life. Think for example about the finding that newborns imitate facial gestures (e.g., Meltzoff & Moore, 1985), a finding that has been regarded by some as an adaptation (e.g., Bjorklund, 1987). However, there are also many adaptations such as bipedal locomotion (approximately one year after birth), antipredator behavior (Barrett, 1999; during the first year of life), language (during the second year of life), and secondary sex characteristics (during puberty) that are not present in very young children. What this suggests is that the timing of an adaptation is not a strict criterion to call a behavior or characteristic adaptive (Buss, Haselton, Shackelford, Bleske, & Wakefield, 1998; Confer et al., 2010; Howe & Otgaar, 2013). However, such studies are critical to determine the proximate mechanisms involved in the development of adaptive memory (Howe & Otgaar, 2013).

In the present article, we report on three experiments that examined developmental trends in adaptive memory using different paradigms. As mentioned earlier, studies have revealed that the adaptive memory effect is present in child samples (Aslan & Bauml, 2012; Otgaar & Smeets, 2010; Otgaar et al., in press). In our view, the early emergence of this effect in childhood is not so much an indication of the development of a particular adaptive behavior, but rather a demonstration of the ontogeny of well-known general memory processes. Indeed, memory mechanisms such as distinctiveness effects (e.g., features that distinguish between stimuli) are important in memory from infancy (Rovee-Collier & Cuevas, 2009) onward (Howe, 2006, 2011b). Item (e.g., stimulus-specific features), relational (e.g., common features among stimuli), and gist processing (e.g., processing the semantics of information; Brainerd, Reyna, & Ceci, 2008) also emerge early in memory and have developmentally invariant characteristics across childhood (Howe, 2006, 2011b).

The principal purpose of this study is to examine whether adaptive mnemonic advantages are developmentally invariant for different stimuli and paradigms and whether certain general memory mechanisms can perhaps partially account for the oft-observed mnemonic advantages for fitness-relevant processing and stimuli. Therefore, in the present manuscript, we report three experiments in which both children and adults were tested in each experiment and in which free recall performance was measured. Furthermore, to bolster the idea that adaptive memory benefits are developmentally invariant, we made use of intentional (Experiment 1) and incidental paradigms (Experiments 2 and 3), used different word (Experiments 1 and 3) and picture (Experiment 2) stimuli, and included different types of material (unrelated [Experiment 3], survival-, negative-, and neutral-related words [Experiments 1 and 2; see also Table 1]). Furthermore, to test whether different general memory mechanisms underlie survival processing, each experiment focused on different specific memory mechanisms (see below). Our idea is that this combined approach is likely to reveal which proximate mechanisms play a role in the survival processing effect and whether this effect is truly developmentally invariant.

To be more specific, in Experiment 1, we examined 11-year-olds' and adult participants' memory performance when they were presented with neutral, negative, and survival-related wordlists that foster memory illusions (Deese/Roediger-McDermott (DRM) wordlists; Deese, 1959; Roediger & McDermott, 1995). These wordlists consist of associatively related words that are linked to a non-presented theme word called the critical lure. Studies show that in recall and recognition tests, many participants erroneously recollect the critical lure (e.g., Brainerd, Reyna, & Ceci, 2008). Furthermore, because of the associative nature of these lists, it is highly likely that these lists boost relational processing and elaborative processing. If relational processing is associated with adaptive memory benefits, then we would expect to find higher recall levels *and* higher memory illusion rates for the survival wordlists than for the other word lists. In this way, using these lists is an effective approach to investigate the role of relational processing on the survival processing advantage (see Burns et al., 2010 for a similar procedure with categorically-related wordlists).

In Experiment 2, 7/8-year-olds, 11/12-year-olds, and adults were enrolled in a standard *incidental* survival-processing paradigm using neutral, negative, and survival-related pictures. Although pictures could enhance the distinctiveness of stimuli, possibly reducing differences between survival and control groups, previous work has shown the opposite effect (Otgaar et al., 2010). Indeed, we predicted that there would be a survival processing advantage and that survival pictures would be better recollected than control pictures. Experiment 3 was conducted in order to evaluate a different type of elaboration as a possible proximate mechanism underlying the survival processing effect (Howe & Derbish, in press; Kroneisen & Erdfelder, 2011) as well as to examine developmental trends associated with this mechanism. That is, in this experiment, participants received the standard survival instruction or a modified survival instruction (or a pleasantness condition). In the modified survival instruction, participants were granted fewer opportunities to engage in elaborative processing because only one survival problem was present in this instruction. If elaboration plays a vital role in the survival recall effect, then the survival recall effect should be diminished in this new survival condition.

Experiment 1

Method

Participants

A total of 70 participants were tested in this experiment. The 11-year-olds (*M* = 11.4 years, *SD* = 4 months) were 35 (17 male, 18 female) predominantly White, middle class children whose parents/guardians gave written informed consent and the child's assent was obtained on the day of testing. The adults (*M* = 18.6 years, *SD* = 7 months) were 35 (18 male, 17 female) university students who gave informed, written consent on the day of testing. The ethical board for the university gave approval for this study.

Design, Materials, and Procedure

The experiment was a 3(List type: neutral, negative, survival) x 2(Age: 11-year-olds, 18-year-olds) repeated measures design where age was manipulated between- and list type within-participants. Fifteen 10-item lists were selected from the word association norms of Nelson, McEvoy, and Schreiber (1998): five lists consisting of high associates of neutral critical lures (*mountain, school, fruit, bread, money*), five lists consisting of high associates of negative critical lures (*sad, bad, fat, cry, anger*), and five lists consisting of high associates of survival critical lures (*death, hurt, sick, war, fight*) (for additional information about how these lists were constructed and how they were rated for their survival relevance, see Howe & Derbish, 2010). The words with the greatest backward associative strength (BAS) to the critical lures were included in each list. All three list types were equated on BAS, semantic density, word frequency, word familiarity, meaningfulness, number of attributes, and imageability. The negative and survival lists were also equated on valence and arousal (see Howe & Derbish, 2010).

We included survival-related lists because not only does survival processing itself produce memory advantages but so too do survival-relevant materials (Howe & Derbish, 2010). Therefore, children and adults were involved in an *intentional* memory task involving survival-relevant lists. That is, based on an adaptive memory account, one would expect that survival-related concepts (e.g., *injury, death, virus, war*) should be remembered differently than concepts that are not directly linked to survival. Moreover, as survival-related words are more likely to be emotionally laden, we also included non-survival-related words that were also emotionally laden (negative words). We added these words to prevent any effects of arousal or valence that might be related to the survival-related words.

Upon arrival, participants were given standard memory instructions. Lists were then presented orally in descending order of associative strength, one word at a time, with two seconds between each word. Four lists of each type were randomly selected for presentation to each participant (counterbalanced across participants within each age group). For each participant, lists were presented in blocks (4 neutral, 4 negative, 4 survival) with the order of blocks also counterbalanced across participants within each age group. After each list was presented, participants were given a 30-sec distractor task (circling random letter pairs in randomized alphabet strings) to eliminate short-term memory and serial position effects.

Participants were then asked to orally recall as many words as they could from the previous list. This study-distractor-test procedure was repeated until all 12 lists had been presented and recalled.

Results and Discussion

Because there were no effects due to blocking or gender, and because there were no theoretical predictions concerning these variables, they were removed from subsequent analyses. The proportion of targets correctly recalled and the number of critical items falsely recalled were calculated and analyzed in separate 3(List type: neutral, negative, survival) x 2(Age: 11-year-olds, 18-year-olds) analyses of variance (ANOVAs). For true recall, there was a significant main effect of age, $F(1, 68) = 83.11$, $p < .001$, $\eta_p^2 = .68$, where 11-year-olds ($M = .56$) recalled fewer items than adults ($M = .72$). There was also a main effect for list type, $F(2, 136) = 22.78$, $p < .001$, $\eta_p^2 = .21$, where post-hoc (Tukey's HSD) tests showed that survival items ($M = .67$) were recalled better than neutral ($M = .49$, $p < .001$) and negative ($M = .41$, $p < .001$) items, and these latter list types did not differ reliably. There was no Age x List type interaction.

For false recall, there was a main effect for age, $F(1, 68) = 24.89$, $p < .001$, $\eta_p^2 = .36$, where 11-year-olds ($M = .31$) falsely recalled fewer critical items than adults ($M = .46$). There was also a main effect for list type, $F(2, 136) = 10.45$, $p < .001$, $\eta_p^2 = .10$, where post-hoc (Tukey's HSD) tests showed that false recall rates were higher for survival items ($M = .35$) than for neutral ($M = .24$, $p < .01$) and negative ($M = .20$, $p < .01$) items, and these latter list types did not differ reliably. There was no Age x List type interaction.

Overall, these results show that items related to survival are better remembered than either negative or neutral material. Moreover, like previous research that has focused on the effects of survival material (as opposed to survival processing) on memory performance (Howe & Derbish, 2010; Experiment 3), false memories were also more frequent for survival lists than neutral or negative lists. Importantly, the present research extends these effects to child participants and provides strong evidence for developmental invariance. That is, regardless of age, true and false recall rates were higher for survival-related material than neutral or negative materials. Together, these results show that with an intentional memory paradigm, memory prefers the retention of survival material and development of memory illusions for survival-related material. Our results imply that relational processing is predominant for survival-related material resulting in an increased propensity for memory illusions. In other words, it is likely that survival-related information consists of a highly dense and interrelated network with nodes that are strongly connected to each other. When activation spreads through such a network, memory retention becomes enhanced and false memory illusions become fuelled (see also Toglia, Neuschatz, & Goodwin, 1999).

In Experiment 2, we adopted the standard incidental survival-processing paradigm in which participants had to imagine a survival or moving scenario or had to rate stimuli for pleasantness. Also, in this experiment, we presented 7/8-year-olds, 11/12-year-olds, and adults with pictures instead of words. We included a younger age group (7/8-year-olds) to examine whether survival processing would also appear at younger ages and test whether we could replicate earlier work on survival processing advantages in younger children (Aslan & Bauml, 2012; Otgaar & Smeets. 2010). To build on the work of Experiment 1, participants received neutral (e.g., clouds), negative (e.g., pistol), and survival-related (e.g., spider) pictures. We expected to find a survival processing advantage and show that survival-related pictures were better recollected than the other pictures.

Experiment 2

Participants

We tested 135 participants with 34 7/8-year-olds (mean age = 7.59, *SD* = 0.50, 15 girls), 39 11/12-year-olds (mean age = 11.59, *SD* = 0.50, 16 girls), and 62 undergraduate students (mean age = 20.73, *SD* = 1.85, 46 women). Children were recruited from elementary schools from the south of the Netherlands and students were undergraduates from the Faculty of Psychology and Neuroscience, Maastricht University. Children received a small present and adults were awarded a financial reimbursement (7.50 euro) or course credits for their participation.

Design, Materials, and Procedure

We used a 3(Age: 7/8-year-olds, 11/12-year-olds, and adults) x 3(Condition: survival, moving, and pleasantness) x 3(Stimulus type: neutral, negative, and survival) split-plot design with the latter factor being a within-subjects variable. Participants were involved in the original survival-processing paradigm (Nairne et al., 2007). Participants were randomly assigned to the different scenarios (survival: *n* = 46, moving: *n* = 44, pleasantness: *n* = 45). Participants received a Dutch translation of one of these instructions:

Survival "In this task, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic materials. Over the next few months, you'll need to find steady supplies of food and water and protect yourself from predators. We are going to show you some pictures, and we would like you to rate how relevant each picture would be in this survival condition. Some of the pictures may be relevant and others not-it's up to you to decide."

Moving "In this task, we would like you to imagine that you are planning to move to a new home in a foreign land. Over the next few months, you'll need to locate and purchase a new home and transport your belongings. We are going to show you some pictures, and we would like you to rate how relevant each picture would be in this moving condition. Some of the pictures may be relevant and others not-it's up to you to decide."

Pleasantness "In this task, we are going to show you some pictures, and we would like you to rate the pleasantness of each picture. Some of the pictures may be pleasant and others may not-it's up to you to decide."

After the instructions, the participants had to rate 30 pictures (for each stimulus type 10 pictures) for survival or moving relevance (1 = not relevant, 5 = extremely relevant), or pleasantness (1 = not pleasant, 5 = very pleasant). Pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1995). The negative (e.g., *theft, explosion*) and survival (e.g., *spider, drowning*) pictures were more emotionally negative (M = 3.20, SD = 0.73) and more arousing (M = 5.60, SD = 0.93) than the neutral (e.g., *flower, plate*) pictures (valence: M = 5.64, SD = 0.94; arousal: M = 2.66, SD = 0.69; both ps < .001). The pictures were unrelated to each other and also bore no relationship with set of words used in the first experiment. Two practice pictures were presented before the start of the experiment. Each picture was shown for 8 s. on a computer screen. To ensure that children understood the concept of survival in relation with the pictures, a pilot study was conducted with 13 children who were not involved in this experiment (mean age = 9.46, SD = 1.94) in which they received the 30 pictures and had to rate on a 7-point smiley scale (1 = not survival-relevant, 7 = extremely survival-relevant) how survival-relevant each picture was. Furthermore, to each child, the concept of survival was explained using the instruction of Nairne and colleagues (2007). Our results showed that the survival pictures received significantly higher survival ratings (M = 5.91, SD = 0.64) than the negative (M = 4.56, SD = 0.63) and neutral pictures (M = 1.71, SD = 0.87; $F(2,24) = 65.28$, $p < .001$, $\eta_p^2 = 0.92$).

After the rating task, participants were presented with a 2-min distractor task (Tetris). Following this, they were asked to recall all the pictures they could remember. This recall task lasted for 10 min.

Results and Discussion

Because no effect of gender on rating and proportion recall was detected, gender was excluded from subsequent analyses. Turning to the rating data, a 3(Age: 7/8-year-olds, 11/12-year-olds, and adults) x 3(Condition: survival, moving, and pleasantness) x 3(Stimulus type: neutral, negative, and survival) repeated measures ANOVA was conducted. We found a significant Age x Condition x Stimulus type interaction ($F(8,252) = 2.20$, $p < .05$, $\eta_p^2 = 0.07$). Performing simple effects analyses, our results showed that for the survival pictures, younger and older children in the survival (7/8-year-olds: $M = 3.94$; 11/12-year-olds: $M = 3.25$) and moving (7/8-year-olds: $M = 3.56$; 11/12-year-olds: $M = 3.72$) group gave significantly higher ratings than children in the pleasantness group (7/8-year-olds: $M = 1.68$; 11/12-year-olds: $M = 1.78$; ps < .05). No significant differences emerged for the adults. A similar pattern was evident for the negative pictures: Higher ratings were provided by children in the survival (7/8-year-olds: $M = 3.80$; 11/12-year-olds: $M = 3.23$) and moving (7/8-year-olds: $M = 3.59$; 11/12-year-olds: $M = 3.52$) group relative to children in the pleasantness group (7/8-year-olds: $M = 1.73$; 11/12-year-olds: $M = 1.68$; ps < .05). Again, no difference was present for the adult ratings. For the neutral pictures, we found that all participants gave significantly higher ratings ($F(4,126) = 10.72$, $p < .001$; $\eta_p^2 = 0.15$) in the pleasantness condition ($M = 3.25$) than in the survival ($M = 2.73$) and moving ($M = 2.52$) conditions.

When we performed a similar analysis on the recall data, the following findings emerged. Our analyses revealed a significant Age x Condition x Stimulus type interaction ($F(8,252) = 2.20$, $p < .05$, $\eta_p^2 = 0.07$; Figure 1). Simple effect analyses showed that as expected, a survival recall advantage was found. Interestingly, however, this effect was more pronounced for survival pictures that were rated by adults. Specifically, adult participants in the survival condition (M = .63) remembered significantly more survival-related pictures than adults in the moving (M = .51) and pleasantness condition (M = .53, $p < .05$). This pattern was not present for child samples. What we did find was that for the negative pictures, a survival recall effect was evident for the 11/12-year-olds in that they recollected more information in the survival condition (M = .41) than in the moving (M = .32) and pleasantness (M = .29, $p < .05$) condition. Also, for the youngest age group, evidence was also present for a survival processing advantage for the neutral pictures. Here, 7/8-year old children in the survival condition (M = .33) remembered significantly more neutral pictures than children in the moving (M = .25) and pleasantness (M = .23) conditions. All other effects were not significant.

For pure exploratory reasons and to examine congruity effects, we also included the ratings (ratings for the different types of pictures) as covariates in our model and examined whether our findings would differ. However, the covariates did not have a significant effect on the recall measures (all ps > .05)

To summarize, we found a survival processing advantage in all age groups but it differed as a function of stimulus type. That is, for the adults, a survival processing advantage was detected for the survival pictures. For the 11/12-year-olds, a survival processing advantage was found for the negative pictures, while for the 7/8-year old children, neutral pictures displayed a survival processing advantage.

We also examined whether participants recollected incorrect pictures as a function of Condition. A univariate ANOVA demonstrated a significant main effect of Condition. Post-hoc Tukey HSD tests showed that participants in the survival condition (M = 0.35) made significantly more errors than participants in the pleasantness condition (M = 0.11; $p < .05$).

Although the moving group (*M* = 0.27) had lower error rates than the survival group, this difference was not significant.

This experiment replicates and extends previous adaptive memory work using pictures (Otgaar et al., 2010). That is, like Otgaar and colleagues (2010), we also found that adults displayed a survival recall advantage when pictures were employed as stimuli. However, the current experiment adds that this was only the case for the *survival-related* pictures. For the other types of pictures (negative and neutral), no mnemonic benefit emerged when pictures were rated for survival-relevance. What this result shows is that it is not only survival processing itself that fuels memorability but also the type of material. Together, survival processing and survival-related material (i.e., pictures) seem to propel mnemonic advantages. This has also been corroborated in other studies (e.g., Howe & Derbish, 2010) and is in line with Experiment 1 that showed that predominantly survival material gains memory precedence. Although we did not show that children showed similar survival-related memory benefits for survival-related material, we did find some evidence that for negative pictures, the older children displayed a survival processing advantage and that for the neutral pictures, a survival processing advantage was present for the younger children. Collectively, the results of this experiment show that for the younger and older children and adults, tentative evidence exists that they preferentially process pictures according to survival-relevance.

Interestingly, Experiment 2 also showed that more erroneous pictures were recollected when participants were in the survival condition relative to the pleasantness condition. This fits nicely with the data from Otgaar et al. (2010) that yielded similar results. As mentioned in Experiment 1, it is likely that this effect is due to the survival instruction leading to increased relational processing, thereby increasing error rates. Indeed, we know from previous studies that survival processing likely leads to increased false memory rates probably because of more reliance on gist traces or associative activation (Howe & Derbish, 2010; Otgaar & Smeets, 2010; Otgaar et al., in press; Smeets, Otgaar, Raymaekers, Peters, & Merckelbach, 2012). However, it must also be noted that the increase in error rates for the survival condition did not reliably differ from the moving condition.

One issue that remains vital is what proximate mechanism underpins this survival processing advantage. In Experiment 1, we showed that the relational nature of survival material is likely to accrue superior memory performance. Other proximate mechanisms have also been receiving attention. Kroneisen and Erdfelder (2011, p.1554) for example argued that "the degree to which survival processing invites elaborative, distinctive forms of encoding would predict the mnemonic benefit of survival processing." So, according to this interpretation, the grasslands scenario results in participants thinking more easily of a number of related features than other scenarios. These features would in turn create many retrieval cues that together boost recall.

To examine this issue, Kroneisen and Erdfelder (2011) included an extra survival scenario in which the number of survival problems was significantly reduced. That is, in the original survival scenario, participants have to imagine being faced with a number of problems (i.e., no food, no water, in danger of predator) that increases the likelihood for elaborative processing. The new survival scenario that they used included only one problem (i.e., no water). When this new scenario was pitted against the moving group, the survival recall advantage vanished thereby suggesting that this new scenario reduced the opportunities to engage in elaborative processing. The purpose of Experiment 3 was to test whether children would similarly show a disappearance of the survival processing advantage when they are confronted with fewer possibilities for elaborative processing. Because distinctiveness effects appear early in development, one could predict to find similar effects in children.

Experiment 3

Participants

Sixty-one 11/12-year-olds (mean age = 11.62, *SD* = 0.49; 33 boys) and 60 undergraduate students (mean age = 22.50, *SD* = 4.68; 13 men) were included in this experiment. Children were recruited from primary schools from the south of the Netherlands and students were undergraduates from the Faculty of Psychology and Neuroscience, Maastricht University. Children received a small award and adults were given a financial compensation (7.50 euro) or course credits for their participation.

Design, Materials, and Procedure

We used a 2(Age: 11/12-year-olds vs. adults) x Condition (survival, survival-short, pleasantness) between-subjects design. Participants were randomly allocated to the different conditions (survival: n = 40; survival-short: n = 40; pleasantness: n = 41). Participants in the standard survival and pleasantness condition received the same instructions as in Experiment 2 (except that they were told that they were presented with words instead of pictures). Participants in the survival-short condition received a Dutch translation of the instruction used by Kroneisen and Erdfelder (2011).

Survival-short “In this task, we would like you to imagine that you are stranded in the grasslands of a foreign land. After searching along the surrounding area and the debris flushed to the shore, you are bound to realize that you have a major problem of survival: you have no potable waters. We are going to show you a list of words, and we would like you to rate how relevant each word would be in this survival condition. Some of the words may be relevant and others not-it’s up to you to decide.”

After receiving the instructions, participants received 30 neutral, unrelated words that had to be rated according to each scenario. These words were the same words as used in Nairne and colleagues first study (2007), but translated into Dutch (e.g., mountain, pepper, book). The words were also not related to the pictures and words used in the first two experiments. Words were presented on a computer screen for 5 s. each. Two practice items were included to familiarize the participant with the task. Ratings were made on a 5-point Likert scale (1 = not relevant, 5 = extremely relevant; 1 = not pleasant, 5 = very pleasant). Following the rating task, a short filler task was included (Tetris) that lasted for 2 min. Finally, a recall phase lasting 10 min. was presented.

Results and Discussion

Because gender did not affect rating and recall performance, it was excluded from further analyses. With respect to the rating data, we found a significant main effect of Condition ($F(2,117) = 29.52$, $p < .001$, $\eta_p^2 = 0.34$). Specifically, post-hoc Tukey HSD tests showed that the pleasantness group ($M = 3.26$) gave significantly higher ratings than the survival ($M = 2.74$) and survival-short ($M = 2.46$, $p < .05$) groups. Furthermore, the survival group had significantly higher ratings than the new survival group ($p < .05$). All other effects were not significant.

Regarding our recall data, results demonstrated a significant main effect of Condition ($F(2,117) = 6.01$, $p < .01$, $\eta_p^2 = 0.09$). Remarkably, Tukey HSD tests showed the following: Both the original survival ($M = .36$) and survival-short group ($M = .36$) had significantly higher true memory rates than the pleasantness group ($M = .29$; $p < .05$). As can be seen, the two survival scenario groups did not differ significantly from each other. Furthermore, a significant Age effect was detected ($F(1,117) = 35.89$, $p < .001$, $\eta_p^2 = 0.24$) with adults ($M = .40$) remembering more words than children ($M = .\ 28$). The Age x Condition interaction effect was not significant.

Like Experiment 2, we also explored whether the recall data were affected by the ratings of the participants. Therefore, we ran the analyses again including the ratings as covariate.

Although the effect of ratings on recall was significant ($p < .001$), the pattern of findings did not change thereby excluding the possibility that ratings affected our recall data.

We also looked at the effect of survival processing on the reporting of incorrect words. Although both the original grasslands condition ($M = .55$) and the survival-short condition ($M = .53$) had higher error rates than the pleasantness condition ($M = .27$), this difference was not significant ($p = .13$). We also found a significant main effect of Age ($F(1,117) = 7.20$, $p < .01$, $\eta_p^2 = 0.06$) with adults ($M = .62$) being more susceptible to the creation of memory errors than children ($M = .28$).

In sum, the results of this experiment nicely reveal that both survival contexts (i.e., original and new condition) result in superior memory performance thereby underscoring the robustness of survival processing effects on memory. However, it seems that this result is at odds with the findings of Kroneisen and Erdfelder (2011) who found that the adapted survival condition resulted in lower memorability than the original grasslands condition (see Experiment 1) and did not differ from a control moving condition. According to Kroneisen and Erdfelder (2011), the explanation of this effect was due to the new survival context causing less elaborative processing, thereby reducing the chance for superior recall.

Two issues are imperative with respect to this discrepancy in findings. First, one might argue that we used another control condition (i.e., pleasantness) compared to the one (i.e., moving) used by Kroneisen and Erdfelder (2011) and that this inconsistency was the basis of the divergent findings. However, previous studies have not found the moving and pleasantness condition to differ from each other in terms of overall memory performance (e.g., Nairne et al., 2007). So, it is unlikely that a different control condition is related to differences between our study and that by Kroneisen and Erdfelder (2011). Second, although Kroneisen and Erdfelder (2011) argue that their new shortened scenario results in less elaborative processing and thereby leads to fewer recall possibilities than the original survival condition, in their second experiment they do not find any significant memory differences between the original and adapted survival contexts. This is perfectly in line with our results. This suggests that it is probable that the adapted survival scenario may not be the best method to study elaborative processing and that in our study, the effect of survival processing on memory was stable in both survival scenarios.

Still, some differences do remain between our study and that of Kroneisen and Erdfelder (2011) that might have led to divergent results between the two studies. First of all, we used a 2-min distractor period as has been done in Nairne et al. (2007) while Kroneisen and Erdfelder used a longer period (10 min.). Although it is unclear what precise effect this could have exerted, it is known that the survival processing advantage can vary when small changes are inserted (Kroneisen & Erdfelder, 2011). Second, in our third experiment, we found lower recall performance for the original survival group than what has been found in Nairne et al. (2007) and Kroneisen and Erdfelder (2011). This could be due to the fact that our sample size was smaller than that of Kroneisen and Erdfelder, something that may have resulted in less power weakening the likelihood of finding statistically reliable effects. Future studies should therefore examine whether these differences might indeed be related to the inconsistency in findings.

General Discussion

The purpose of the current series of experiments was to examine developmental trends in adaptive memory and determine whether survival-processing effects were developmentally invariant using a variety of stimuli and paradigms. The results of these experiments provide compelling evidence that the survival processing advantage is developmentally invariant. From an evolutionary standpoint, our results support the idea that it is likely that selection pressures from our ancestral past left " footprints" in our memory system. These footprints have less to do with a predisposition to favor the processing of survival-relevant information and more to do with the greater likelihood of engaging various proximate mechanisms (e.g., elaboration, distinctiveness) in these tasks. Moreover, our experiments show that this adaptive memory predisposition is present in children and adults.

In Experiment 1, we used an intentional memory paradigm to tackle the issue of developmental trends in the processing of survival-relevant materials. Testing 11-year-olds and adult participants, we found that when neutral, negative, and survival DRM word lists were presented memory was superior for the survival-related words. This finding demonstrates that survival-related materials also enjoy a mnemonic benefit but also that, because of the relational nature of the DRM word lists, false memories were more easily elicited for the survival word lists relative to other word lists. This lower net accuracy for survival information extends earlier work on survival processing and false memories (Howe & Derbish, 2010; Otgaar & Smeets, 2010; Otgaar et al., in press) by demonstrating that these false memory effects also occur in child samples and especially for survival material. Furthermore, Experiment 1 showed that the survival mnemonic benefits are probably caused by increased relational processing and elaborative processing since the survival word lists were more associatively rich than the other lists.

Experiment 2 used the typical survival-processing paradigm including neutral, negative, and survival-related pictures and 7/8-, 11/12-year-olds, and adults. Like the first experiment and in accordance with previous work (Otgaar et al., 2010), we found partial evidence for the survival processing effect in all age groups. Interestingly, we found that this effect was mainly present for the survival-related pictures. However, this only occurred for the adult participants. For the 7/8-year-olds, neutral pictures enjoyed a survival memory preference and for the 11/12-year-olds, a survival processing advantage was just present for the negative pictures. So, although we replicated earlier results on the survival-processing paradigm using pictures, this experiment adds that all types of pictures are likely to exhibit the usual survival processing advantage, but that it likely depends on the age which type of picture enjoys a survival memory benefit. Although it is not completely evident why in this experiment the survival processing effect was dependent on the type of material for different age groups, one possible solution could be that we used an intentional memory approach in Experiment 1 while we used an incidental one in Experiment 2. It is possible that survival-related material is better remembered for all age groups when an explicit instruction is provided to remember those pictures than when no explicit instruction is provided. The result could then be that more attention and resources are allocated to survival-related material relative to other material resulting in better memory for survival-related material.

The finding that pictures also demonstrate a survival processing advantage might be seen as surprising as research shows that pictures are more distinctive than for instance words that might result in increased memorability for all conditions (and not specific for the survival condition; e.g., Mintzer & Snodgrass, 1999). On the other hand, it might also be the case that this picture superiority effect (Rajaram, 1996) results in larger survival processing effects for pictures than words because of increased deep processing of pictures relative to words. Indeed, dual-coding theories stipulate that pictures activate both verbal and nonverbal (pictorial) coded memory thereby leading to superior mnemonic advantages for pictures (Craik & Lockhart, 1972; D'Agostino, O'Neill, & Paivio, 1977; Hyde & Jenkins, 1973). Relatedly, studies suggest that from an evolutionary stance, humans had to process pictures (images) at an earlier stage (Paivio, 2007) than words implying that the survival processing advantage should be quite large with imagery-based materials. Whereas Experiment 1 provided a nice demonstration of the role of relational processing and elaboration as a proximate mechanism in the development of adaptive memory effects, Experiment 2 provided a similar demonstration for the role of distinctiveness.

In Experiment 3 we extended our understanding of the role of elaboration using a method employed by Kroneisen and Erdfelder (2011). According to these authors, the survival processing effect stems for elaborative processing because the survival scenario grants participants a multitude of opportunities to engage in elaboration. By providing participants with a scenario in which only one survival problem was present (i.e., no potable water), it is more difficult to elaborate with respect to this scenario thereby reducing memorability. When we contrasted this new survival scenario with the original scenario (and pleasantness condition), we, however, found that for both 11/12-year-olds and adults, these scenarios did not differ in terms of memory recollection. What we did find was that both scenarios outperformed the pleasantness condition thereby demonstrating the classical survival processing advantage. So, our survival processing manipulation was effective in terms of memory performance.

As mentioned before, even Kroneisen and Erdfelder (2011) found in one of their experiments (Exp. 2) that these two scenarios did not statistically differ from each other in terms of memorability. Thus it seems that this new survival scenario might not be the best solution to manipulate elaborative processing. More work needs to be done to test the locus of these divergent findings, with one promising avenue being to vary the levels of elaborative processing across a variety of processing tasks. Indeed, when this was done with adults, the survival processing advantage disappeared and memory performance was determined by the extent of elaborative processing regardless of scenario (Howe & Derbish, in press).

In addition, Howe and Derbish (in press) reasoned, like Kroneisen and Erdfelder (2011), that the grasslands scenario might require greater elaboration than other scenarios (e.g., moving, going on holiday) simply because they are relatively unfamiliar and would have to draw on things participants might have read or seen on television. Indeed, such ancestral scenarios would not have been experienced by modern humans so considerable imagination would have to be used to rate items for survival as requested by the experimenter. When equally unfamiliar but non-ancestral scenarios (stranded on a foreign planet, stranded under the sea) whose elaboration requirements were rated as similar to that of the usual survival-processing tasks were used, the survival processing advantage vanished. Thus, it is highly likely that the usual survival-processing scenarios spontaneously engage participants to use more elaboration and imagination than when more familiar scenarios are employed.

Equally important in this debate is that even non-ancestral and unusual scenarios also led the survival processing advantage disappear. That is, Soderstrom and McCabe (2011) compared the standard survival scenario with a scenario in which participants had to imagine being attacked by zombies. Obviously, this zombie scenario is quite unusual and not ancestrally relevant. Like Howe and Derbish (in press), the survival processing advantage disappeared. So, these just-mentioned findings imply that the use of such unusual scenario might be an alternative to study elaborative processing in the adaptive memory field.

Regarding the developmental course of adaptive memory, our argument is that finding a survival processing effect early in childhood is not a definite sign to call this effect adaptive. As Howe and Otgaar (2013, p. 17) specified "[a]lthough we may all eventually exhibit an advantage for storing and retrieving fitness-relevant information, the ontogenetic course of the emergence of this adaptive memory effect may vary considerably." Therefore, we suggest that well-documented mechanisms such as elaboration, relational, and item-specific processing are factors that underlie the benefits observed when participants engage in survival processing or study survival-related materials. Because these processes have been shown to possess developmentally invariant characteristics (Howe & Otgaar, 2013), it is more likely that these processes are related to fitness advantages in memory. Indeed, our experiments nicely show that this is the case.

Another important result of the current experiments is that we found tentative evidence for increased error rates in the survival condition and survival material relative to the other conditions and other material. Previous work has also shown that survival processing and survival material enhances the susceptibility to memory errors (Howe & Derbish, 2010; Nairne et al., 2007; Otgaar & Smeets, 2010; Otgaar et al., in press; Smeets et al., 2012). Of course, it is likely that proximate mechanisms as relational and elaborative processing are the driving catalysts in these effects. Although one might postulate that errors are not in line with an evolutionary idea, evidence is accumulating that in certain circumstances, memory errors are adaptive. Take for example an experiment by Dewhurst, Thorley, Hammond, and Ormerod (2011) that found that elevated memory errors are positively related with convergent thinking; an aspect of creativity. Another example is the finding that memory errors prime solutions of complex problem solving tasks (e.g., Howe, Garner, Charlesworth, & Knott, 2011). Together, these findings show that under certain circumstances, memory errors can have positive and adaptive consequences (Howe, 2011a; Schacter, Guerin, & St. Jacques, 2011).

This leaves us with the question what our findings say about the evolutionary background of memory. It seems clear now that adaptive memory benefits are developmentally invariant. Our experiments replicate previous studies (Aslan & Bauml, 2012; Otgaar & Smeets, 2010) and add that adaptive memory effects hold for children and adults even when using different stimuli and paradigms. One might be tempted to conclude that these findings fit well with the idea that humans possess a sort of adaptive memory adaptation to preferentially process survival-relevant information (Nairne et al., 2007). As we have outlined earlier, an equally plausible alternative possibility is that our experiments imply that certain well-known memory principles as relational processing (Experiments 1 and 3) and distinctiveness (Experiment 2) might be present at an early stage and that these drive superior memory retention.

It is undoubtedly true that our memory evolved out of certain selection pressures, yet one may wonder whether a certain simple survival instruction might be the key to unlock certain adaptive memory mechanisms. What our and other recent studies (e.g., Klein, in press) show is that survival processing itself might not be special after all and that other memory principles might underlie the survival memory effect (Howe & Otgaar, 2013; Otgaar, Jelicic, & Smeets, 2013). Of course, this is not to deny the evolutionary existence of adaptive memory, but we believe the examination of these general memory principles in relation to survival processing might shed vital light into the foundation of adaptive memory. Such a research avenue would broaden our knowledge about the proximate mechanisms behind adaptive memory and tell us why memory is significant for our survival.

References

Anderson, J. R. & Milson, R. (1989). Human memory: An adaptive perspective. *Psychological Review*, *96*, 703-719.

Aslan, A., & Bauml, K.-H. T. (2012). Adaptive memory: Young children show enhanced retention of fitness-related information. *Cognition, 122,* 118-122.

Bjorklund, D.F. (1987). A note on neonatal imitation. *Developmental Review, 7*, 86-92.

Brainerd, C.J., Reyna, V.F., & Ceci, S.J. (2008). Developmental reversals in false memory: A review of data and theory. *Psychological Bulletin, 134,* 343

Burns, D. J., Burns, S. A., & Hwang, A. J. (2011). Adaptive memory: Determining the proximate mechanisms responsible for the memorial advantages of survival processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 206-218.

Buss, D.M. (2009). *Evolutionary psychology: The new science of the mind* (4th ed.). Boston: Allyn & Bacon.

Buss, D.M., Haselton, M.G., Shackelford, T.K., Bleske, A.L., & Wakefield, J.C. (1998). Adaptation, exaptations, and spandrels. *American Psychologist, 53,* 533-548.

Confer, J.C., Easton, J.A., Fleischman, D.S., Goetz, C.D., Lewis, D.M.G., Perilloux, C., & Buss, D.M. (2010). Evolutionary psychology. Controversies, questions, prospects, and limitations. *American Psychologist, 65,* 110-126.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior*, *11*, 671-684.

D'Agostino, P. R., O'Neill, B. J., & Paivio, A. (1977). Memory for pictures and words as a function of level of processing: Depth or dual coding? *Memory & Cognition*, *5*, 252-256.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58,* 17-22.

Dewhurst, S.A., Thorley, C., Hammond, E.R., & Ormerod, T.C. (2011). Convergent, but not divergent, thinking predicts susceptibility to associative memory illusions. *Personality and Individual Differences, 51*, 73-76.

Gould, S.J., & Lewontin, R.C. (1979). The spandrels of San Marco and the Panglossian paradigm: A critique on the adaptationist programme. *Proceedings of the Royal Society of London*, *205*, 581-598.

Howe, M. L. (2006). Developmental invariance in distinctiveness effects in memory. *Developmental Psychology, 42*, 1193-1205.

Howe, M. L. (2011a). The adaptive nature of memory and its illusions. *Current Directions in Psychological Science, 20,* 312-315.

Howe, M. L. (2011b). *The nature of early memory: An adaptive theory of the genesis and development of memory.* New York: Oxford University Press.

Howe, M. L., & Derbish, M. H. (2010). On the susceptibility of adaptive memory to false memory illusions. *Cognition*, *115*, 252-267.

Howe, M.L. & Derbish, M.H. (in press). Adaptive memory: Survival processing, ancestral relevance, and the role of elaboration. In B. Schwartz, M. L. Howe, M. Toglia, & H. Otgaar (Eds.), *What is adaptive about adaptive memory?* New York: Oxford University Press.

Howe, M. L., Garner, S. R., Charlesworth, M., & Knott, L. (2011). A brighter side to false memory illusions: False memories can prime children’s and adults’ insight-based problem solving. *Journal of Experimental Child Psychology, 108*, 383-393

Howe, M. L., & Otgaar, H. (2013). Proximate mechanisms and the development of adaptive memory. *Current Directions in Psychological Science, 22,* 16-22.

Hyde, T. S., & Jenkins, J. J. (1973). Recall for words as a function of semantic, graphic, and syntactic orienting tasks. *Journal of Verbal Learning & Verbal Behavior*, *12*, 471-480.

Kang, S. H. K., McDermott, K. B., & Cohen, S. M. (2008). The mnemonic advantage of processing fitness-relevant information. *Memory & Cognition*, *36*, 1151-1156.

Klein, S. (in press). A role for self-referential processing in tasks requiring participants to imagine survival on the savannah. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Klein, S., Cosmides, L., Tooby, J., & Chance, S. (2002). Decisions and the evolution of memory: Multiple systems, multiple functions. *Psychological Review, 109*, 306-329.

Klein, S., Robertson, T.E., & Delton, A.W. (2011). The future-orientation of memory: Planning as a key component mediating the high levels of recall found with survival processing. *Memory, 19*, 121-139.

Kroneisen, M., & Erdfelder, E. (2011). On the plasticity of the survival processing effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 1553-1562.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1995). *International affective picture system (IAPS): Technical manual and affective rating*s (Tech. Rep. A-4). Gainesville, FL: University of Florida, Center for Research in Psychophysiology.

Meltzoff, A.N., & Moore, M.K. (1985). Cognitive foundations and social functions of imitation and intermodal representation in infancy. In J. Mehler & R. Fox (Eds.), *Neonate cognition: Beyond the blooming, buzzing confusion* (pp. 139-156). Hillsdale, NJ: Erlbaum.

Mintzer, M.Z.,& Snodgrass,J.G.(1999).The picture superiority effect: Support for the distinctiveness model. *American Journal of Psychology, 112,* 113–146.

Nairne, J. S., Thompson, S. R., & Pandeirada, J. N. S. (2007). Adaptive memory: Survival processing enhances retention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 239-243.

Nairne, J. S., & Pandeirada, J. N. S. (2010). Adaptive memory: Ancestral priorities and the mnemonic value of survival processing. *Cognitive Psychology*, *61*, 1-22.

Nairne, J. S., Pandeirada, J. N. S., & Thompson, S. R. (2008). Adaptive memory: The comparative value of survival processing. *Psychological Science*, *19*, 176-180.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. Available: http://www.usf.edu/FreeAssociation

Otgaar, H., Howe, M. L., Smeets, T., Raymaekers, L., & van Beers, J. (in press). Memory errors in adaptive recollections. In B. Schwartz, M. L. Howe, M. Toglia, & H. Otgaar (Eds.), *What is adaptive about adaptive memory?* New York: Oxford University Press.

Otgaar, H., Jelicic, M., & Smeets, T. (2013). *Adaptive memory: Item-specific, relational, and elaborative processing in the survival processing advantage*. Submitted for publication.

Otgaar, H., & Smeets, T. (2010). Adaptive memory: Survival processing increases both true and false memory in adults and children. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 1010–1016.

Otgaar, H., Smeets, T., Merckelbach, H., Jelicic, M., Verschuere, B., Galliot, A., & van Riel, L. (2011). Adaptive memory: Stereotype activation is not enough. *Memory & Cognition, 39,* 1033-1041.

Otgaar, H., Smeets, T., & van Bergen, S. (2010). Picturing survival memories: Enhanced memory for fitness-relevant processing occurs for verbal and visual stimuli. *Memory & Cognition*, *38*, 23-28.

Paivio, A. (2007). *Mind and its evolution: A dual coding theoretical approach.* Mahwah, NJ: Erlbaum.

Rajaram, S. (1996). Perceptual effects on remembering: Recollective processes in picture recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 365-377.

Roediger, H. L., & McDermott, K. (1995). Creating false memories: Remembering words not presented in a list. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 803-814.

Rovee-Collier, C., & Cuevas, K. (2009). Multiple memory systems are unnecessary to account for infant memory development: An ecological model. *Developmental Psychology, 45*, 160-174.

Savine, A. C., Skullin, M. K., & Roediger, H. L., III (2011). Survival processing of faces. *Memory & Cognition*, *39*, 1359-1373.

Schacter, D.L., Guerin, S.A., & St. Jacques, P.L. (2011). Memory distortion: An adaptive perspective. *Trends in Cognitive Sciences, 15,* 467-474.

Scott-Phillips, T.C., Dickins, T.E., & West, S.A. (2011). Evolutionary theory and the ultimate-proximate distinction in the human behavioral sciences. *Perspectives on Psychological Science, 6,* 38-47.

Seamon, J.G., Bohn, J.M., Coddington, I.E., Inslee, E., Ebling, M.C., Grund, E.M., Haring, C.T., Jang, S., Kim. D., Liong, C., Paley, F.M., Pang, L.K., & Siddique, A.H. (2012). Can survival processing enhance story memory? Testing the generalizability of the adaptive memory framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 1045-1056.

Smeets, T., Otgaar, H., Raymaekers, L., Peters, M. V., & Merckelbach, H. (2012). Survival processing in times of stress. *Psychonomic Bulletin & Review*, *19*, 113-118.

Soderstrom, N. C. & McCabe, D. P. (2011). Are survival processing memory advantages based on ancestal priorities? *Psychonomic Bulletin & Review, 18*, 564-569.

Toglia, M.P., Neuschatz, J.S., & Goodwin, K.A. (1999). Recall accuracy and illusory memories: When more is less. *Memory, 7,* 233-256.

Tse, C., & Altaribba, J. (2010). Does survival processing enhance implicit memory? *Memory & Cognition, 38,* 1110-1121.

Weinstein, Y., Bugg, J. M., & Roediger, H. L., III (2008). Can the survival recall advantage be explained by basic memory processes? *Memory & Cognition*, *36*, 913-919.

Authors' Note

Henry Otgaar and Tom Smeets, Clinical Psychological Science, Faculty of Psychology and Neuroscience, Maastricht University, the Netherlands. Mark L. Howe, Department of Psychology, City University London, Northampton Square, London, EC1V 0HB, UK, and Sarah R. Garner, Department of Psychology, Lancaster University, Lancaster UK.

Dr. Otgaar's contributions were supported by a grant from the Netherlands Organization for Scientific Research (NWO; 016.135.052 and by a grant from the Edmund Hustinx Foundation). Professor Howe's contribution was supported by a grant (RES-062-23-3327) from the Economic and Social Research Council, UK.

Address correspondence to either Henry Otgaar (henry.otgaar@maastrichtuniversity.nl) or Mark L. Howe (Mark.Howe.1@city.ac.uk).

Dr. Steve Dewhurst acted as action editor on this manuscript.

Table 1

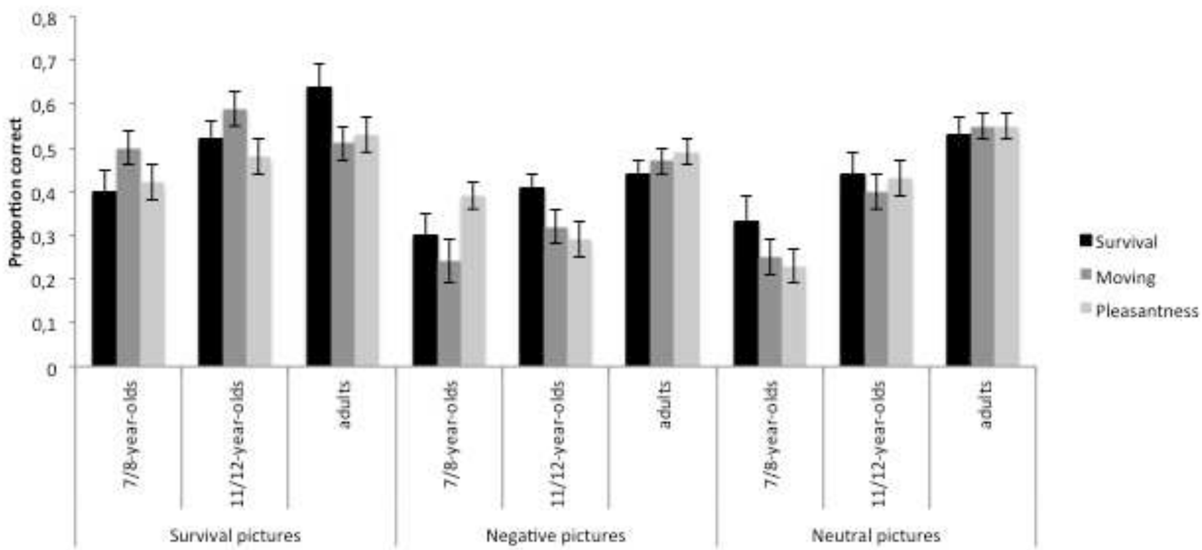
Commonalities and differences between the three experiments

Experiment	Ages	Study Material	Conditions	Retrieval task
1	11, Adult	Thematic lists	Neu; Neg, Sur	Recall (intentional)
2	7/8,11/12, Adult	Pictures	Neu; Neg; Sur	Recall (incidental)
3	11/12, Adult	Unrelated words	Sur, Sur-short, Pleas	Recall (incidental)

Note: Neu=Neutral, Neg=Negative, Sur=Survival, Pleas=Pleasantness

Figure

Figure 1. Proportion correct recall of survival-related, negative, and neutral pictures as a function of Condition and Age (error bars represent standard error of means).



0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Proportion correct
7/8-year-olds
11/12-year-olds
adults
7/8-year-olds
11/12-year-olds
adults
7/8-year-olds
11/12-year-olds
adults
Survival pictures
Negative pictures
Neutral pictures
Survival
Moving
Pleasantness