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Using the background to remember the foreground: the role of contextual information in memory

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Introduction

Environmental context-dependent memory is a ubiquitous memory phenomenon that is intuitive and easy to relate to everyday experience. It is also at the core of most cognitive theories attempting to explain human memory function. No memory theory would be complete without postulating a role for the processing of contextual information (see also Chapter 4) and a mechanism through which the reinstatement of encoded contextual information at retrieval contributes to item memory. Considering how important context is for memory function, it is perhaps not surprising that there is much debate about its role and the nature of its contribution. Understanding the role of context in memory function as fully as possible is crucial for many theoretical and practical reasons; among these, the need to understand of the effects of age-related and neurodegenerative changes on memory function, and how this knowledge may contribute to the development of techniques and strategies for helping people with memory preservation.

The nature of environmental context-dependent memory

Environmental context (EC) refers to information that is peripheral to the memory target. The term peripheral does not necessarily refer solely to the spatial properties of the information but also to its relationship with the target; EC is incidental in the sense that it does not affect the interpretation of the target (cf. semantic context; Light & Carter-Sobell, 1970) and participants are not explicitly instructed to meaningfully associate the target with the context (cf. Eich, 1985). EC will be the focus of this chapter, although other types of context information will be considered. Most would be familiar with the influence of EC on memory in everyday life.

One example would be realising you need a specific item located in another room in the house. Once you reach that other room, you have forgotten what it was you needed. Importantly, you remember again when you return to the original room. Presumably, the item needed is remembered because memory is aided by the environmental cues that were present when the thought of needing the item was initially formed. Another example would be returning to a former place of residence after a long time of absence. Such an experience is often accompanied by the apparent re-emergence of memories associated with the place, possibly of events that might have been considered forgotten otherwise.

In addition to anecdotal evidence, EC-dependent memory has a long research history. Many of the early studies suggest the influence of associationism and the principle of contiguity, which purports that items contiguous in space and/or time are likely to become mentally linked. On the basis of this principle, it is inevitable to hypothesise that encoding information in a specific physical or mental environment will create a link between the information and the environment such that, when the environment is reinstated, the retrieval of the information is facilitated. Early in the history of psychology, Carr (1913) conducted a series of experiments to test the effects of several environmental manipulations on the learning of a maze by a rat (e.g., illumination, cleanliness of the maze). He concluded that “an experience can be recalled most readily in those environmental situations with which it has the most direct, the strongest and the most numerous associations” (Carr, 1925, p. 250). Since then, many studies have been conducted demonstrating the effects of EC on memory employing a variety of different experimental designs. A classic and very frequently cited study was conducted by Godden and Baddeley (1975) employing the reinstatement paradigm. In the reinstatement paradigm, encoding takes place in one EC and, at retrieval, the encoding EC is reinstated or changed. An EC effect is observed if retrieval is superior when the encoding EC is reinstated. In Experiment 1, Godden and Baddeley employed divers as participants. They encoded a list of words aurally either on land or while diving underwater. Subsequently, participants retrieved the words using written free recall either in the same EC as the one at encoding or in the different EC. Participants retrieving in the encoding EC recalled significantly more items than the participants who switched, regardless of what the testing environment was (i.e., on land or underwater).

Since the Godden and Baddeley (1975) study, others have employed a variety of less extreme environmental manipulations to demonstrate the EC reinstatement effect. One of the most common EC manipulations involves rooms. Smith, Glenberg and Bjork (1978, Experiment 3) instructed participants to sort words into categories in one of two different rooms. At encoding, participants were not aware that another room was involved in the study or that their memory would be tested later. Therefore, the significance of the environment did not become apparent until retrieval, if at all. A day later, participants returned to the same room where encoding had occurred or to the other room, and their memory was tested via free recall. As anticipated, retrieval was superior when it occurred in the original encoding EC. Other studies employing the EC reinstatement paradigm have included background and font colour manipulations (e.g., Markopoulos, Rutherford, Cairns, & Green, 2010), testing in person or via telephone (Canas & Nelson, 1986) and more (see Smith & Vela, 2001, for a review).

Interestingly, Smith (1985) employed music as EC in two experiments. A crucial difference with previous EC reinstatement experiments is that the music manipulation allowed for a condition where the encoding EC was not reinstated but was not changed either. Using music as EC allowed for a 'no context' condition, where participants were exposed to music at encoding and to quiet (as opposed to different music) at retrieval. The pattern of results confirmed that it is not the change in context between encoding and retrieval that reduces performance per se, but rather it is the reinstatement of the encoding context at retrieval that has a beneficial effect probably through a cuing effect.

Such experimental findings are consistent with the Encoding Specificity Principle (ESP) as formulated by Tulving and Osler (1968) and Tulving and Thomson (1973). The ESP states that a retrieval cue will be effective in cueing the target item only to the extent that information in the cue was present and incorporated in the memory trace during encoding. An impressive demonstration of the principle was provided by Tulving and Thomson (1973). At Stage 1, target words were presented and encoded along with a weakly associated word (e.g., BLACK – train). At Stage 2, participants completed a filler task. The apparently unrelated filler task was to generate six associates to words that, unbeknownst to the

participants, were strong associates of the target words from Stage 1 (e.g., WHITE). A large number of target words were produced in response (e.g., WHITE: black). At Stage 3, participants performed a recognition test on the associates they had produced and attempted to identify the ones they had seen at Stage 1 (e.g., BLACK). At the fourth and final stage, cued recall was tested where the cue provided was the weakly associated word paired with the target at encoding (e.g., train for the target BLACK). Participants performed better at cued recall at Stage 4 than at recognition at Stage 3, demonstrating that recognition is not always easier than recall. More critically, weakly related associates were shown to be more effective retrieval cues than strong associates, presumably because the weak associates were encoded along with the target. This result is consistent with the ESP and with EC-dependent memory, both of which place emphasis on the match between encoding and retrieval conditions. Specifically, the ESP and related theories such as Global Activation Models (e.g., Hintzman, 1988) would suggest that there is a direct and causal relationship between retrieval cue and memory trace match and retrievability.

The ESP, although both intuitive and supported by empirical evidence, has faced some criticism. Baddeley (1997) points out that the principle involves a circular argument. If a retrieval cue is effective, it is assumed that it is effective because it matches the memory trace formed at encoding. If a retrieval cue is not effective, the assumption made is that it does not match the memory trace sufficiently. Therefore, it is practically impossible to produce evidence against the principle (see an analogous circular argument in relationship to levels of processing in Chapter 4). A second criticism relating to the first is expressed by Nairne (2002), who argues that retrieval is not a function of the match between the cue and the memory trace, but that retrieval depends on the usefulness of the cue in distinguishing between the memory trace and competing or distracting items. According to Nairne, the relationship between cue-trace match and retrievability is correlational rather than causal. When the retrieval cue matches the memory trace, it is more likely to assist in differentiating between the target and competing items. This rather subtle point is illustrated very effectively by a thought experiment provided by Nairne (2002); at encoding, participants are asked to read aloud a list of homophones in a particular order (1: write, 2: right, 3: rite, etc.). At retrieval, half of the participants are asked to recall in writing the third word from the list (i.e., rite). The other half of the participants are provided with an

additional retrieval cue and are told that the target word sounds like 'rayt'. According to the ESP, the second condition provides a relatively increased match between the retrieval cues and the memory trace. Therefore, the second group should demonstrate higher recall probability. However, in this particular instance, the increased cue-trace match does not help differentiate between the target (rite) and other competing items (write, right). An important point to be made is that Nairne's argument and the ESP itself refer to the functional match rather than the nominal match. In other words, they refer to the relationships formed in the participant's mind rather than to any objective relationship between the presented stimuli. This is the main reason Nairne has employed thought experiments to illustrate his point. Actual experimental manipulations can only indirectly explore functional relationships, making it difficult to eliminate alternative interpretations. However, there is empirical evidence that can be interpreted to support Nairne's position (e.g., Goh & Lu, 2012).

The criticisms aimed against the ESP also largely transfer to EC-dependent memory studies. With regard to Nairne's (2002) argument, it is very probable that not all EC manipulations will result in better retrieval performance when the encoding and retrieval ECs match due to the potentially poor diagnostic value of the cues provided. Indeed, EC reinstatement effects are typically not particularly strong (see Smith & Vela, 2001) and they are frequently not observed at all. The rather modest effect sizes of EC reinstatement studies are to be anticipated and they are actually desirable. Learning something in a specific EC and largely forgetting the information learnt, if required to retrieve it elsewhere, would not be a property of an effective memory system. Consistent with this idea, null effects in EC reinstatement studies have often been observed (e.g., Fernandez & Glenberg, 1985). EC reinstatement effects have also been elusive when recognition memory is tested as opposed to free recall (e.g., Godden & Baddeley, 1980; cf. Smith & Vela, 2001). Additionally, few studies have obtained reverse EC reinstatement effects, with retrieval performance being superior when the retrieval EC does not match the encoding EC (e.g., Markopoulos, 2005; McDaniel, Anderson, Einstein, & O'Halloran, 1988). Such unexpected results cannot be readily explained, but they do suggest that EC effects can vary dramatically and are sensitive to differences in instructions and tasks at encoding and retrieval.

In an attempt to extrapolate patterns and explain apparent inconsistencies in the EC-dependent memory literature, Smith and Vela (2001) conducted a review and meta-analysis. They included studies that manipulated incidental context as defined earlier in this section, employed human participants, and operationalised EC as global as opposed to local. The distinction between global and local EC is not very clear. Typically, global EC is operationalised through the use of rooms, while local EC is operationalised as the background colour of the screen on which the target stimuli are presented and/or the position and font colour of the stimuli (see Markopoulos et al., 2010). Although Smith and Vela only included global EC manipulations, it is not clear if the two types of EC produce different behavioural results or involve different mechanisms in how they operate (cf. Markopoulos, 2005). Some revealing patterns and conclusions were drawn from the meta-analysis. For one, mental reinstatement of the EC appears to be as effective in cuing the target stimuli as physical EC reinstatement. In other words, at retrieval, it is not essential that the encoding EC is physically present for EC reinstatement effects to occur as long as the participants are reminded of the encoding EC or spontaneously choose to mentally reinstate it as a retrieval strategy. Additionally, some evidence was found that EC effects are reduced when attention is drawn away from the EC at encoding (overshadowing) and/or at retrieval (outshining) through the provision of more effective or stronger cues. These findings are consistent with Nairne's (2002) position that effective cues are more diagnostic. EC cues will be more effective (and diagnostic) when other cues are not available. Smith and Vela's work is highly valuable and it generated several important conclusions and testable hypotheses. However, many questions still remain particularly with regard to reverse EC reinstatement effects, the relationship between global and local EC and their respective underlying mechanisms, and a full taxonomy of EC.

Context and the brain

In recent years, much progress has been made in terms of understanding how memory operates and how the underlying hypothesised mechanisms involved relate to specific brain areas and functions. This progress is largely attributable to neuroimaging technology, which has brought cognitive psychology and neurophysiological research closer together. Even before such technological advances, the role of the medial temporal lobe (MTL) and the

hippocampus in particular in episodic memory was well-established, if not fully understood, through lesion studies and research in the amnesic syndrome (e.g., Scoville & Milner, 1957). Episodic memory involves the encoding and retrieval of specific episodes or events as opposed to general knowledge (see Tulving, 1983). What differentiates it from other types of memory is that the event (i.e., memory item) is accompanied by peripheral information such as when, where and under what circumstances the event took place (i.e., context information). Part of the contribution of recent neuroimaging literature is in attempting to determine the precise role of specific MTL regions and other brain areas in the processing of item and context information, and how these regions coordinate to result in the effective encoding and retrieval of episodic memories.

One particularly influential theory of how item and context information relate to specific brain regions has been the BIC (Binding of Item and Context) account as expressed by Diana, Yonelinas and Ranganath (2007). On the basis of a review of neuroimaging studies employing different methods and materials to distinguish between the processing of item and context information during encoding and retrieval, a model was formulated that identifies three main MTL regions as having distinct roles. The perirhinal cortex (PrC) processes item information, the parahippocampal cortex (PhC) processes context information (spatial and non-spatial), while the hippocampus processes item-context associations. An interesting prediction of the model is that although the hippocampus supports item-context associations and therefore associative retrieval, when the item and context are 'unitised' and processed as a single item, the PrC will be involved. This prediction has been supported by several studies. In an fMRI study, Haskins, Yonelinas, Quamme and Ranganath (2008) scanned participants during the encoding of unrelated word pairs. Word pairs were either presented within a sentence or they formed novel compound words (unitisation condition). At test, recognition memory was tested for intact or rearranged word pairs outside the scanner. In agreement with the BIC model prediction, PrC activation at encoding was higher for word pairs forming novel compound words than for pairs presented in a sentence. Both the BIC model and the unitisation prediction suggest that the manner in which contextual information is processed may have dramatic effects in which specific brain areas are involved. Despite this caveat, there is abundant evidence of the involvement of PhC in the processing of context information, and several theories

concur with BIC although they differ in their theoretical assumptions and the interpretation of the evidence (e.g., Davachi, 2006; Montaldi & Mayes, 2010).

Models such as BIC (Diana et al., 2007) are based on neuroimaging studies that typically do not investigate the incidental influence of EC on memory as discussed in the previous section. Instead, they utilise experimental paradigms exploring associative memory or memory for context. Therefore, although the role of PhC in the intentional encoding and retrieval of context information has been demonstrated, it is not clear whether it has a role in EC reinstatement effects. It is impractical, if not impossible, to manipulate global EC in conjunction with fMRI measurements. However, Hayes, Nadel and Ryan (2007) explored this issue in an fMRI study testing object memory and manipulating local EC (Experiment 5). Everyday objects were presented at encoding either in a naturalistic scene or isolated in a white background. Encoding was incidental and participants were not given instructions regarding the background scenes. At retrieval, participants completed a recognition test for the objects. Three main conditions were employed: objects presented in a scene were tested in the same scene (scene-scene), objects presented on white background were tested on white background (object-object) and objects presented in a scene were tested on white background (scene-object). Recognition performance was superior in the same EC condition (scene-scene) than in the different EC condition (scene-object). Brain activity at encoding showed that PhC was associated with subsequent retrieval success in the scene-object and the scene-scene conditions but not in the object-object condition. At recognition, PhC activity was associated with retrieval success in the scene-object condition. Brain activity at recognition was contrasted between hits in the scene-object condition and hits in the object-object condition. This analysis revealed increased PhC activity in the scene-object condition, suggesting the possibility that the PhC is involved in the mental reinstatement of the encoding EC, which in turn facilitates correct item recognition. Overall, the neuroimaging evidence presented here strongly indicates the involvement of the MTL – if not specifically the PhC – in EC reinstatement effects.

The role of context in Alzheimer's disease

Alzheimer's disease (AD) is a type of dementia characterised by gradually progressive neurodegeneration, often preceded by mild cognitive impairment (MCI). MCI is defined as presenting signs of memory impairment and subjective memory complaints in the absence of additional cognitive impairments, which would be present in mild AD (see Albert et al., 2011, for MCI criteria, and McKhann et al., 2011, for AD criteria). Reflecting the progressive nature of AD, Braak and Braak (1991) have identified six stages of the disease on the basis of an extensive post-mortem study that allowed the specification of the brain damage involved at each stage. The earliest stages of AD involve damage of the entorhinal cortex (ErC), which is an MTL region and part of a pathway linking the hippocampus to neocortical areas. The damage eventually progresses to other MTL regions and later to neocortical areas. Consequently, the first cognitive impairment to manifest in AD is anterograde amnesia – which corresponds to a difficulty in acquiring new information.

It has been suggested that, in early AD, item memory is selectively impaired with context memory and/or context-bound memory being largely intact (Didic, Barbeau, Felician, Tramon, & Guedj, 2011). This hypothesis is consistent with the initial damage of anterior sub-hippocampal structures, which include ErC and PrC. Additionally, it is consistent with BIC (Diana et al., 2007). Provided the posterior MTL including PhC remains intact, it is possible that context processing remains functional for considerably longer (i.e., including stages 1 and 2; Braak & Braak, 1991). However, more substantial experimental evidence is required to test this hypothesis further – this may not prove easy, however, since, as Didic et al. (2011) reasonably assume, context-rich memory impairment is more likely to result in an AD diagnosis.

Contrary to the hypothesis formulated by Didic et al. (2011), there is substantial evidence that context-based memory is impaired considerably early in AD, while item processing still remains relatively unimpaired. This pattern of pathology in AD is so widely accepted that tasks based on the ESP are employed for early diagnosis of AD on the basis that AD patients do not seem to fully benefit from the matching cues at encoding and retrieval (e.g., Adam et al., 2007). Della Barba (1997) employed the Remember-Know task (Tulving, 1985), which involves participants classifying recognition judgments on whether context details were also retrieved (Remember) or the retrieved item only felt familiar (Know). Della Barba (1997)

found that AD patients produced fewer Remember responses than controls, but they did not differ in terms of Know responses, and they even produced more correct Know responses than controls in certain conditions. Irrespective of theoretical perspectives (see Yonelinas, 2002), it is widely agreed that Remember responses require context processing while Know responses reflect item memory. Also, according to the BIC model, Remember responses rely on the integrity of the hippocampus and the PhC, while Know responses rely on the integrity of the PrC. Similar findings have been obtained with other measures and paradigms, including source memory (i.e., memory for the context information present at encoding), with AD patients manifesting substantial misattribution errors (e.g., Mitchell, Sullivan, Schacter, & Budson, 2006). The Remember-Know task and source memory are both paradigms employed by studies reviewed by Diana et al. (2007), further suggesting the involvement of PhC and the hippocampus in memory for context.

Similar results to those obtained by Della Barba (1997) with AD patients have been obtained with MTL amnesic patients, with amnesic patients producing fewer Remember responses than controls but not differing in item-based Know responses (e.g., Aggleton et al., 2005). One of the early explanations for the amnesic syndrome that gathered much support was the Context Memory Deficit hypothesis (Mayes, 1988) which purported that MTL amnesic patients' memory problems originated from a failure to process contextual information. Since then, the hypothesis has evolved further, incorporating current theoretical perspectives, but the key role of context information processing remains (see Kopelman & Bright, 2012).

The use of context in rehabilitation

Haj and Kessels (2013) conducted a review of the literature on context memory in AD. Studies exploring EC reinstatement effects are conspicuously absent, while most reviewed studies focus on memory for context or employ semantic context in the form of word pairs. Haj and Kessels hypothesise that impaired context memory may be compensated for by the provision of cues from encoding on the basis of the ESP, although they do not mention EC reinstatement specifically. However, there is some indirect evidence that AD patients may benefit from EC reinstatement. Barak, Vakil and Levy (2013) tested traumatic brain injury

(TBI) patients and controls using a variety of materials and different types of retrieval tests. TBI patients have different pathology to people with AD but their episodic memory impairment is rather similar at the early stages of AD. Barak et al. (2013) employed the EC reinstatement paradigm using rooms to manipulate encoding and retrieval EC match. EC reinstatement effects were obtained for both TBI patients and healthy controls. The effects were stronger for free recall than for cued recall, and no effects were obtained for recognition. These findings partially concur with Smith and Vela's (2001) meta-analysis suggesting an outshining effect with EC cues employed less at retrieval the more other cues are available. Interestingly, TBI patients benefitted more from EC reinstatement than controls. This finding demonstrates that episodic memory patients may benefit from EC reinstatement (see also Fernandez & Alonso, 2001, for similar findings with healthy elderly participants). Perhaps more importantly and quite counter-intuitively, it suggests that intact memory for context is not necessary for EC reinstatement effects to occur.

Considering the findings of Barak et al. (2013), the behavioural and neuroimaging literature presented in this chapter, and the key role of context in theories of episodic memory, a more exhaustive and systematic investigation of EC reinstatement effects in AD patients may prove to be critical for the development of rehabilitation techniques. Memory stimulation techniques for AD patients based on ESP have been explored to some degree with promising results (see Grandmaison & Simard, 2003). However, the evidence is scarce and based on non-longitudinal studies using semantic or category membership cues. Therefore, global and local EC reinstatement paradigm studies need to be conducted with AD patients at all stages of the disease, employing a variety of encoding and retrieval tasks, and different types of EC operationalization. On the basis of the evidence presented here, a reasonable hypothesis is that AD patients would manifest stronger EC reinstatement effects than healthy controls because of – rather than in spite of – their impairment in processing associative information. If the outshining and overshadowing principles are valid (Smith & Vela, 2001), it is possible that AD patients will benefit relatively more from the reinstatement of incidental EC information in the absence of stronger or more diagnostic cues, depending on the stage of the disease and the extent of the damage. Therefore, rehabilitation techniques could eventually incorporate EC reinstatement in terms of considering the learning and testing environments, their richness and distinctiveness, the

attention directed to the environments at encoding and at retrieval, and the availability of alternative but perhaps less effective cues.

Conclusion

A clear pattern of memory impairment in AD has not yet been established. Contributing to the lack of consistency is the progressive nature of the disease but also possibly the large variability in the distribution of damage between patients (Braak & Braak, 1991). Another factor may be the focus of neuroimaging studies on MTL. Some fMRI studies have obtained hyperactivations in AD patients outside of MTL, possibly reflecting compensatory activity (see Dickerson & Sperling, 2009). The possibility of compensatory activity by intact brain areas may result in inconsistent findings across studies, but also suggests the development of proper rehabilitation techniques may contribute substantially to the alleviation of AD symptoms. Considering the role of context processing in the manifestation of AD symptoms, rehabilitation technique development must involve a more systematic investigation of EC reinstatement effects both in terms of under what circumstances they are observed and how they are operationalised.

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