LUNDS UNIVERSITET

INSTITUTIONEN FÖR PSYKOLOGI

Memory Integration in a Real-World Setting

Lena-Theresa Bachmeyer

Kandidatuppsats HT 2018

Handledare: Mikael Johansson
Examinator: Farida Rasulzada

Abstract

A fundamental component of episodic memories, allowing for their vividness and detail in recollection, is the visual context accompanying it. At times, it has been found that such memories may bind with one another. In such memory integration, the visual context accompanying the integrated events, may been found to be a key component. Yet, though the importance of context on episodic memories has been realised, little research has investigated them in a realistic every-day life situation. With recent developments in technology, the creation of virtual environments allows for new means to study such memories in a naturalistic yet controlled setting. Through this new approach, this study aims at highlighting the effects of the visual environment on memory integration. This is done using a context overlap paradigm at the time of encoding and retrieval of integrated memories. Data from 18 subjects, in the form of verbal behavioural responses was collected. From these, their success in memory integration as an outcome of the manipulations was assessed. The subject's confidence for each answer given was also noted. No significant difference in memory integration was found when comparing the conditions of context overlap and nonoverlap with one another.

Keywords: virtual reality, episodic memory, memory integration, visual context

Memory Integration in a Real-World Setting

Though the effects of context on episodic remembering, and memory integration have been widely researched, the two mechanisms have only been studied as separate entities. The possible effects of combining context and memory integration, have not yet been researched. Furthermore, though context and its effects on memory have been investigated, the visual elements of it have been induced through the use of background pictures or videos on computer screens. Allowing to study the effects of overlap and absence of diagnostic features on memory integration these may, however, be argued not representative to the visual context experienced in real life. Thus, combining the known effects of context and applying it to the believed mechanisms of memory integration, may be insightful. Due to the context dependent nature of episodic memories, it may also be desirable to study memory integration in a naturalistic setting. One way in which such a setting may be achieved, is the use of virtual reality. Through such computerised environments, settings alike those in the real world may be created and made use of as a substitute.

Episodic Memories

Coined in 1972, the term ‘episodic memory’ refers to a neurocognitive system (Tulving, 2002), that allows to maintain events and ideas about ourselves in a subjective timeline (Tulving, 1983; Clayton, Salwiczek, & Dickinson, 2007). Characterised by the recollection and binding of information, often into individual events, episodic memories distinguish themselves from other kinds of recollection due to their autonoetic awareness (Moscovitch, Cabeza, & Winocur 2016). Considered alike mental time travel, when recalling a specific and personally relevant event, one is able to account for specific details about what happened (Tulving, 1983). The questions of where-what-when are generally answered with ease (Plancher, Gyselinck, & Piolino, 2018). Due to their detailed nature, episodic memories have found to be of high relevance to the individual recalling it. This has been argued be due to that the visual information accompanying the event not only stores factual information. Each context may also stand for the motivations and emotions associated with the event (Mizumori, 2013). Upon recollection of the event, such emotional and motional corresponds of the memory are reexperienced quite vividly and may explain its relevance to the individual. A further way in which these memories distinguish themselves, are feelings of remembering. Episodic memories are solely placed in the past. (Clayton et al., 2007).

Neural Correlates of Episodic Memories

Though several structures have been identified as important contributors in the formation of such episodic memories, the hippocampus is argued to play the central role. Analogous to an engram/code, the hippocampus stores the underlying cortico-structural interactions of the medial temporal lobe (MTL) and neocortex at the time of encoding and allows for their functional reactivation upon recall (Tonegawa, Pignatelli, Roy, & Ryan, 2015). Together, based on the content that is represented (the information that is stored), they give rise to the stored multimodal conscious experience. Such an experience refers to the activation and use of more than one sense modality (e.g. auditory, visual and olfactory). Thus, if the content of the event represents a birthday party, such a multimodal experience may allow for us to reexperience the event in great detail. We may be able to reexperience not only what everything looked like, but information from our other senses active at the time, such as the smell of the candles and taste of the cake frosting. Tying to such functional recollection, the principle of functional-neural isomorphism (F-NI) holds that, representations that differ from one another must have distinct underlying network and as such, be fundamentally different from one another - similar to a scaffold acting as an index to the neocortical representations of the whole memory (Moscovitch et al., 2016). This phenomenology of experience/consciousness is thus argued a reflection of the involved networks themselves, and novel for episodic memories (Moscovitch, 1995).

Memory Integration

Storing information in neural networks, the underlying idea of memory integration maintains that events which share similarities in their experience, are stored together on a neural level. Their sharedness causes for a partial overlap in neural representation, allowing for the flexible nature of memories, their modification as well as distortion of the information they hold (Schlichting & Preston, 2015). Thus, the various components of which our wholesome and detail-rich episodic memories comprise, are rarely a result of direct and common encoding. Rather, due to the flexible nature of such memories, the episodes in question are encoded individually and associated with one another (Zeithamova & Preston, 2010). For two relevant events to successfully be associated with one another, one must find support on which such an inference can be based (Schlichting & Preston, 2015). Such may be found in a common cue that has been encountered separately, at both events. Thus, memory integration is frequently studied using an A-B-C item design. In such a design, the events of A and C are associated/inferred with one another due to the sharing of B. Taking Schlichting and Prestons (2015) dog in the park example; When observing a person (A) walking a dog (B) in the park and at a later point encountering the same dog (B) again, however, with a different person (C) walking it, one may assume some kind of relationship between the persons (A-C). Perhaps they are a married couple, and take turns walking their dog. Thus, as an outcome of the two encounters, two integrated sets of memories as a part of one larger whole, have been created:

Memory 1: Dog and person one walking it (A-B).

Memory 2: Dog and person two walking it (C-B).

Integration: Inferred relationship between the persons, as the outcome of sharing a dog (A-C).

In order to form such an association (e.g. the two persons) guided by a cue (e.g. the dog), the separately created memories must be re-established and combined. In the process of such memory integration, the separate memories must be retrieved and manipulated by recombining and recoding them based on their common cue (Zeithamova et al, 2012). A key mechanism in this process, that allows for such memory integration is inferential reasoning (Zeithamova, Schlichting, & Preston, 2012).

Alike the theory of memory integration, inferential reasoning argues for the tying together of shared elements, existing in separate memories (Backus, Schoffelen, Szebényi, Hanslmayr, & Doeller, 2016). The ability to based on information obtained by our sample, tie together and draw conclusions about the events and future expectations. Focusing on the logical process of inference, such an overlap in neural structure of the initially separately existing memories, are tied together actively through the individual's attempt at answering a novel question (Zeithamova, 2012). Such flexibility allows the making possible of the vast interconnectivity of neural structures and learning of new information as an addition to the existing (Schlichting & Preston, 2015). Tying to the attempt at answering a novel question, investigations on the possible factors that may influence memory integration, found subject awareness to play an important role.

Though shown possible without being consciously aware, task attentiveness has been found to facilitate memory integration. Task attentiveness refers to paying close attention to the task and instructions. This effect is presumed to be shown as task attentiveness can lead to, whether indirectly or instructed, becoming aware of the task structure (Henke, Reber, & Duss, 2013). In turn, this may give rise to the facilitation. Another factor that has been found to aid integration, is the reminding of previous memories which may be related to the new learning instance. Such reminding of previous memories should occur shortly before the new learning is to occur. This idea is based on the malleable nature of memories, allowing them to change and distort. In line with this, as memories have been retrieved, they are more likely to become integrated with the new information presented (Hupbach, Gomez, Hardt, & Nadel, 2007). For this to be possible, the old memory should be retrieved before the new information is presented with little competition between them. The two memories must be able to coexists in order for them to overlap and integrate. In order to validate the behavioural findings, theories and provide further clarity of the supposed mechanism, brain and neural imaging is of great importance in memory research.

An important area that has been associated with the detection of reinstatement of similar information, is CA_1 found in the hippocampus. Through the comparing of new content with what previously has been stored, novel information may be detected. Presented with the new information, the CA_1 sends signal instructions to the nearby CA_3 neurons, which increase their plasticity in order to store the content (Schlichting, Zeithamova, & Preston, 2014). Tying to the neural correlates, a further factor that has been found to aid in the integration of memories (both on a structural and behavioural level), is visual imagery.

Visual Context

The visual context is a key component of episodic memories, allowing for their vivid constitute and detail in recollection. Such remembering is often likened to a summary record of a personally relevant event (Tulving, 1983). The visual elements of such autobiographical memories may function as a foundation upon which the memory is created. A conceptual context into which pieces of information relevant to the instance, are placed (Moscovitch, 2016). The various information components about the event in question, including its emotional relevance, are integrated into the visual context observed during the instance in which the memory was created. This value and effect of the presence of visual features as a component of episodic memories, have been highlighted in numerous studies.

Investigating such benefits and possible limitations of context reinstatement during episodic remembering, the visual context has not always been found beneficial (Johnson, Hashtroudi, & Lindsay 1993; Bramao & Johansson, 2017). Through the combination of brain imaging, and behavioural data in the form of verbal responses, context has only been found beneficial when diagnostic. Commonly indicated by the positive-going event-related brain potential (ERP) generated by the lateral parietal cortex (400-500 ms upon stimuli onset), when a visual environment merely is the context for one event, it functions as a useful means of remembering. On the other hand, indicated by the early anterior ERP (ca 100-300 ms upon stimuli onset), when a visual environment is a shared context, it no longer functions as useful means to recall a specific memory (Bramao & Johansson, 2017). Building and supporting upon this finding, behavioural data suggests similar outcomes. When a context is merely representative of one memory event (diagnostic), memory performance is significantly higher than when it is shared (non-diagnostic).

As mentioned, for the recollection of episodic memories to be possible, the underlying cortical processes active during the creation of the memory must be correctly reinstated/reactivated during its retrieval (Norman & O'Reilly, 2003; Tulving &Thomson,1973). The visual context that accompanies the event-specific memory during encoding, is therefore also of significance during the recollection of it (Rugg et al., 1998¸ Bramao & Johansson, 2018). Allowing us to correctly discriminate between memories and discard the irrelevant competitors, the context of the event and memory in question are a key aspect (Easton, Webster, & Eacott, 2012). Alike the comparison of gene loci on DNA strands to establish a match, novel characteristics of the visual context present during encoding and recollection, facilitate correct memory retrieval. Accurate recall occurs as the majority of the retrieval cues align with the stored information traces, highlighting the diagnostic value in the visual context (Tulving, 1983).

In summary, applying this to a more practical example, daily creating numerous episodic memories in the same or similar contexts, being able to distinguish between them and recall the correct one, is critical. Thus, making use of diagnostic visual features in our environment, allowing us to correctly discriminate between memories and discard the irrelevant competitors, are a key aspect allowing for enhanced remembering (Bramao & Johansson, 2017; Easton, Webster, & Eacott, 2012). If the visual context is not diagnostic, it no longer functions as means to distinguish. However, though the sharing of visual contexts may not always lead to enhanced remembering, it provides the basis for memory integration, another important component of episodic memories (Zeithamova & Preston, 2010).

Visual Context and Memory Integration

Tying these structural ideas to the importance of context, the visual aspects may highlight the wholesome interconnectivity of memory integration further. As stated previously, episodic memories are of a context dependent nature, leading to greater recall success when the context in which a memory was encoded, is reinstated during retrieval (than when it is not) (Bramao & Johansson, 2018). The same importance of context may be found true for memory integration. Forming associations between two separately encoded events, is argued more successful when a shared context is given, than when no context is given (Staudigl and Hanslmayr, 2013). Tyng this finding with that of inference due shared cues, events and contexts are both bound and integrated during encoding. Yet, thought facilitating effects of context on remembering haven been found and it is known that memories may integrate, the possible effects of context on memory integration have not been investigated,

Building on these findings, investigating the effects of context on memory integration may prove insightful and highlight context advantages and limitations further. More specifically, doing so in a naturalistic setting. Previously marked by methodological issues due to the lack of technological developments, this issue has through recent years been overcome to a large extent (Plancher, Gyselinck, & Piolino, 2018). Through the development of virtual environments (VEs), the creation of more real-life appropriate settings has been made possible. This may show to be of significant importance in the study of episodic memories. Argued to heavily rely on the visual context accompanying an event (Tulving, 1983; Schlichting & Preston, 2015), having the visual information presented in a naturalistic setting may show to be beneficial. Making use of various tools, such digital environments may allow to create controlled lab situations, whilst maintaining the naturalistic environment, much alike those in the real world. Comparing to this new approach, investigating the effect of visual context on memory through the presentation of background pictures on a computer screen, can be argued not representative of the experiences had in the real world (Plancher et al., 2018).

Making use of this new approach, this study aims at investigating the effects of the visual environment on memory integration, in a more immersive real-world setting. More precisely, the effects of context overlap versus nonoverlap at the time of encoding and retrieval (E-R) of integrated memories.

Research hypothesis (H_1): Context overlap at E-R facilitates memory integration.
Alternative hypothesis (H_0): Context overlap at E-R, does not facilitate memory integration.

Method

Participants

A total of 18 subjects participated in this study, ranging between 21-34 years of age, with 11 being biological females and 7 biological males. All students of psychology at the university of Lund, each was obtained through convenience sampling. This sampling took place during a lecture they were attending. Individual laboratory times were booked with each subject. Upon their scheduled time of participation, each subject was given a short tour of the lab and equipment used. Thereafter, the written instructions were presented to the subject, through which the study procedure was outlined in detail. After the signing of the written informed consent, and the fitting of the VR-headset, the study began. Upon the completion, subjects were individually debriefed, informed where the study results can be found and provided contact information if they were to have any remarks or questions about the study.

Instruments

Taking a total of 1 hour, the study was separated into 8 blocks, with each containing 2 study phases, 2 familiarisation phases and 1 test phase (see image 1). Throughout the entire study, subjects were to learn the association of 240 items, chosen from the Bank of Standardized Stimuli (BOSS). The normative visual items were grouped based on category belonging (e.g. food, animal) and divided to into 160 triads, across 16 lists.

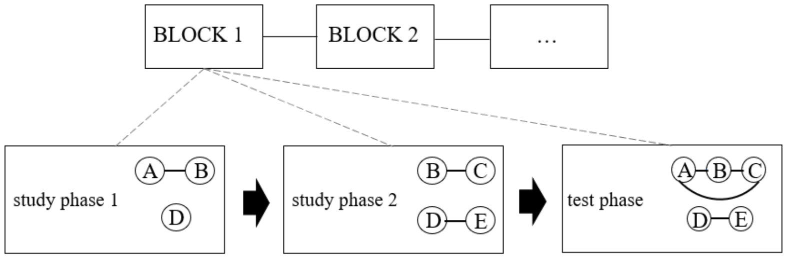

Figure 1. Displays the structure of each block and the groupings of items associated with memory integration (A-C integration based on the encoding of A-B and reencounter of B during B-C) and control (D-E) and the test phase.

Using the PC game engine Unity, a 3-dimensional, 1-floor house was created. Consisting of 7 distinctly different rooms in which the study takes place, these serve as the visual context (see image 2). Through the use of the virtual-reality (VR) headset HTC Vive Pro, attached to a PC on which the experiment was run, the subjects were able to passively navigate in this real-world setting.

The two conditions through which memory integration is investigated, are those of E-R overlap and E-R nonoverlap (see image 3).

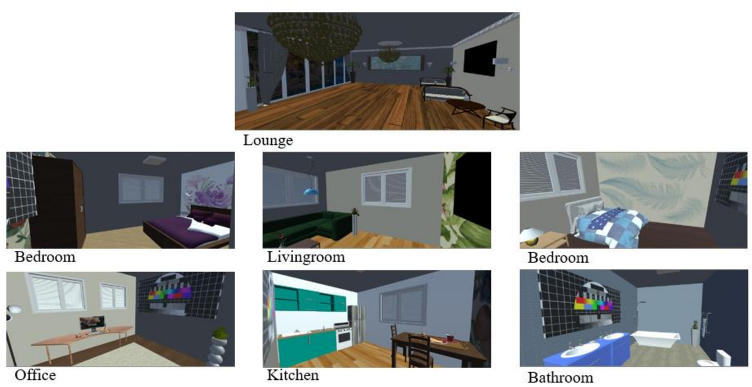

Figure 2. Displays the different VR rooms (lounge, bedroom, living room, bedroom, office, kitchen and bathroom) serving as the contexts during test and study.

Design

The conditions of E-R overlap and E-R nonoverlap were counterbalanced using the ABBA and reverse method. This was applied to all subjects, with the first half starting with the ABBA structure, followed by its reverse during the second half of the experiment. The other half of subjects started with the reverse, followed by the ABBA structure during the second half of the experiment. All items made use of were divided into triads and lists, to allow for the counterbalancing of their possible confounds, and whether they served as memory integration or control items (where no memory integration occurs). This was done by labelling the items of triads A, B and C respectively. The A-B items are the first ones to be encoded (occurring during study phase 1) followed by the corresponding B-C pair during the second study phase (during which memory integration of A-C based on the shared B item, is expected to occur; see image 3). The individually encountered D-E items serve as the control and are also taken from the same set of triads as those of the ABC items. However, used for a different subject. The same list of which the ABC memory integration items were taken, serve as the control items for another subject. In this conversion, it is the B and C items from the previous memory integration, that serve as the control D and E items. Thus, each item should across participants, appear equally often during memory integration opportunities, as control. Additionally, trying to the counterbalancing of conditions, each item should appear equally often during an E-R overlap, as a nonoverlap condition. During the test phase, the correct pair association for all the A-C, A-B, B-C and D-E pairs was tested for. Starting the test phase, all A-C pairs were tested for first, to ensure that no second opportunity for memory integrations is presented. The A-B and B-C pairs for each test opportunity were divided into two groups and intermingled with on another. Controlling for the possible additional learning opportunities of testing one of the pairs before the other, half of the subjects were presented with an A-B test pair upon the completion of the A-C pair test. The other half of subjects were presented with a B-C test pair upon the completion of the A-C pair test. The D-E pairs were tested for intermingled with the A-B and B-C pairs.

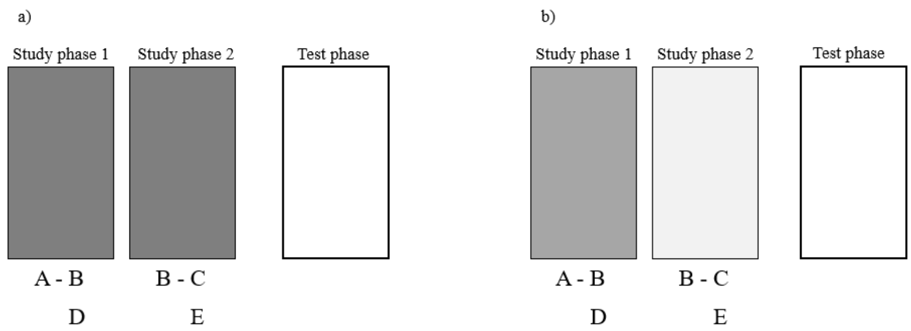

Figure 3. Displays the structure of E-R overlap (a) and E-R nonoverlap (b), along with instances of the associated item pairs.

To ensure that there are no confounding effects of the order of the rooms, these too were counterbalanced. Each room (excluding the lounge) is shown equally many times during E-R overlap conditions and E-R nonoverlap conditions. Due to the ABBA and reverse method, what kind of room is shown, has also been made note of. For instance, 'kitchen' and 'bathroom' are rather naturally associated with one another. Thus, to avoid such an association that may confound and serve as an E-R overlap during nonoverlap, the grouping of rooms has been chosen in relation to their condition.

A total of 8 different versions of the experiment were created, to allow for the counterbalancing of the item stimuli, visual context, memory integration/control and E-R overlap/nonoverlap.

Procedure

Upon the start of the start of the first block, the subjects were presented with the familiarisation phase, during which they should get to know the room in which they are currently present. This should be done in a way that allows the subject to remember it in a detailed manner. The subject is instructed to do this by turning 360 degrees and turning their head as they seem fit. After this first familiarisation phase ends, the first study phase begins. Still positioned in the same room, the subjects' point of view is passively navigated to face a TV-screen located on one of the walls in the room. Instructed to pay attention to this shift, along with ending the exploration of the room, a series of objects are displayed on the screen. Either 1 or 2 objects at a time are shown. If 1 object is show, the subject is asked to simply remember the object, and in which room it has been shown. With 2 objects shown on the screen, the subject is asked to remember that the 2 objects belong together, and in which room they have been presented. Thereafter, before moved into a new room for the second familiarisation phase, the subject is passively moved into the lounge for a short middle stop. This allows for a smooth transition between the rooms and phases. Arriving in the new room for the second familiarisation and study phase, the instructions are the same. In line with the two conditions of E-R overlap and nonoverlap, half of the time the subjects are moved to the second familiarisation phase, they return to the same/different room.

After the completion of 2 familiarisation and 2 study phases, the test phase begins. Passively moved to the lounge, in which all tests occur, the subject is instructed to again focus on a TV-screen presented on the wall in front of them. The forced-choice test begins. For each memory pair to be retrieved, the object in question is presented in the top-middle of the screen. Below on each side marked by #1 or #2, the two choices, of which only 1 is correct, are presented. Upon their choice of which they believe to be the correct one, the subject is asked to rate their confidence in answer given. This is done for all choices. As the test phase ends, so does the block and the subject is moved into a new room for the beginning of a new familiarisation phase. The outlined procedure is done for all 8 blocks.

Data Analysis

Investigating the effects of E-R overlap/nonoverlap on memory integration/inference, the data was collected if the form of verbal behavioural responses. During the test phase, the subjects were asked to verbally answer which of the two alternatives given (#1 or #2), was the correct associated pair with the cue presented. Individually for each subject, their answers given were compared to a sheet of the correct answers for that version. Each subject was also asked to verbally rate their confidence in answer given. These too were noted down.

Calculated in percentage, the correct amount of answers given per subject, were divided into the corresponding pair associations (A-C, A-B, B-C and D-E), as well as the condition to which they belong (E-R overlap or E-R nonoverlap). These data points were entered into SPSS, which was used for all data calculations. Starting with the creation of a scatter-plot for each data point and condition. With the cut-off scores of 0.30 and 0.90, 4 outliers were found and removed. Due to ceiling performance 1 subject was excluded completely. Upon this, as the same subjects were made use of across all conditions, a paired sample *t*-test was used to calculate the data. The aim of this *t*-test is to establish whether there is a significant difference in the overlap and nonoverlap condition, corresponding to the pair association.

For the confidence ratings of each subject, similar calculations were made. As there are no correct answers, each confidence score in association to their pair and condition, were summed. Divided by the maximum possible, the percentage confidence, depending on pair and condition, were noted down into a table displaying all subjects. These too were entered into SPSS in order to perform a paired sample *t*-test. Alike the comparison of correct scores, the aim of conducting such a *t*-test was to establish whether there is a significant difference in the confidence in answer given, depending on the overlap/ nonoverlap condition and pair association.

For the statistically significant result of the first *t*-test, the effect size was calculated using the formula below. The aim of this is to establish the magnitude of the effect. The interpretation guidelines of this value maintain that 0.01 is a small effect size, 0.06 is moderate and 0.14 is considered a large effect size.

Ethics

To allow for anonymous results, all personal information was kept separate from the subject's answers. As the subjects were not given a number or code for identification, the informed consent and subject data cannot be associated with one another. To prevent subject identification from the order of participation, the noted subject's data was randomised in order. This also helps ensuring that which answer were given by what subject, cannot be figured. Besides their name, sex, age, test answers (excluding the last 4 digits of the identification number) and signature confirming their consent and age, no sensitive data was collected. Reason for collecting the sensitive data, is grounded in being a necessity to ensure the subjects understanding of rights, willingness to participate as well as better understanding of the collective data. Through and in connection to the informed consent, subjects were informed about their rights such as anonymity, right to withdraw at any given point and doing so without stating any reason. Upon the completion of the study, each subject was asked about their experience and if they had any questions. All subjects were individually debriefed, notified as to where the study/results can be found, as well as given contact information if they were to have any questions or remarks regarding the study and/or their experience.

Results

Pair Associations

A paired- sample *t*-test was conducted to evaluate the effect of context overlap on memory integration. For the behavioural answers, no statistically significant difference in performance/correct pair associations between the A-C overlap (*M*= 0.56, *SD*= 0.11) and A-C nonoverlap (*M*= 0.54, *SD* =0.11), *t* (16) = 0.56, *p* = 0.58 (two tailed) was found. The decrease in performance scores, from overlap to nonoverlap, was 0.02 with a 95% confidence interval ranging from -0.05 to 0.09.

Comparing the pairs of A-B overlap (*M*= 0.6, *SD*= 0.10) and A-B nonoverlap (*M*= 0.63, *SD*= 0.12), *t* (15) = -1.44, *p* = 0.17 (two tailed) no statistically significant difference was found. The increase in performance scores was 0.03 with a 95% confidence interval ranging from -0.78 to 0.02. For the B-C overlap (*M*= 0.61, *SD*= 0.11) and B-C nonoverlap pair (*M*= 0.57, *SD*= 0.11), *t* (16) = 1.94, *p* = 0.07 (two tailed), no statistically significant difference was found. The decrease in performance scores, from overlap to nonoverlap, was 0.04 with a 95% confidence interval ranging from 0.02 to 1.48.

For the control and single association D-E overlap (*M*=0.62, *SD*=0.09) and D-E nonoverlap (*M*= 0.54, *SD*= 0.11), *t* (14) = 2.75, *p* = 0.016 (two tailed), a statistically significant result was found. The decrease in performance scores, from overlap to nonoverlap, was 0.06 with a 95% confidence interval ranging from 0.02 to 0.15. The eta squared statistic (0.35) indicated a large effect size.

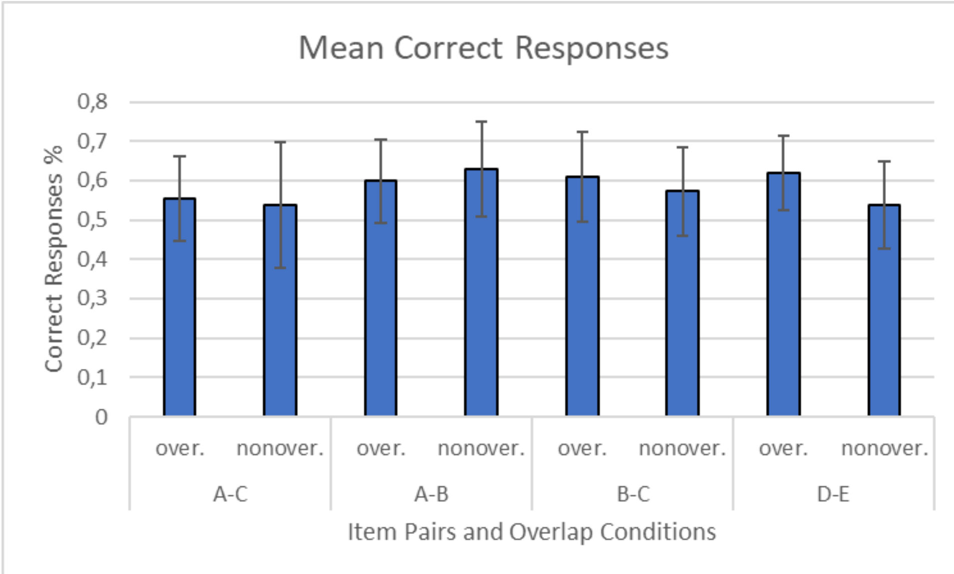

Figure 4. Displays the mean percentage of correct choice responses for the sample pairs A-C, A-B, B-C and D-E with respect to their overlap (over.) and nonoverlap (nonover.) condition. The error bars represent the calculated standard deviation (+/-) for each pair and condition.

Confidence Ratings

A further paired-sample *t*-test was conducted, with the aim to investigate the effect of context overlap on choice confidence for correct responses. Comparing the confidence in answer given for the A-C overlap (*M*= 0.7, *SD*= 0.14) and A-C nonoverlap pairs (*M*= 0.639, *SD*= 0,148), *t* (14) = 0,42, *p* = 0.68 (two tailed) no statistically significant difference was found. The increase in performance scores was 0.02 with a 95% confidence interval ranging from -0.07 to 0.11.

For the A-B overlap (*M*= 0.75, *SD*= 0.09) and A-B nonoverlap pairs (*M*= 0.75, *SD*= 0.12), *t* (14) = 0.05, *p* = 0.96 (two tailed), no statistically significant difference was found. The decrease in performance scores, from overlap to nonoverlap, was 0.01 with a 95% confidence interval ranging from -0.06 to 0.06. Comparing the B-C overlap (*M*= 0.73, *SD*= 0.12) and B-C nonoverlap pairs (*M*= 0.73, *SD*= 0.11), *t* (14) = -0.4, *p* = 0.69 (two tailed), no statistically significant difference in confidence ratings was found. The decrease in performance scores, from overlap to nonoverlap, was 0.006 with a 95% confidence interval ranging from -0.04 to 0.03. For the control pairs of D-E overlap (*M*= 0.75, *SD*= 0.11) and D-E nonoverlap (*M*= 0.73, *SD*= 0.12), t (14) = 1.11, *p* = 0.28 (two tailed) no statistically significant difference was found. The decrease in performance scores, from overlap to nonoverlap, was 0.03 with a 95% confidence interval ranging from -0.02 to 0.08.

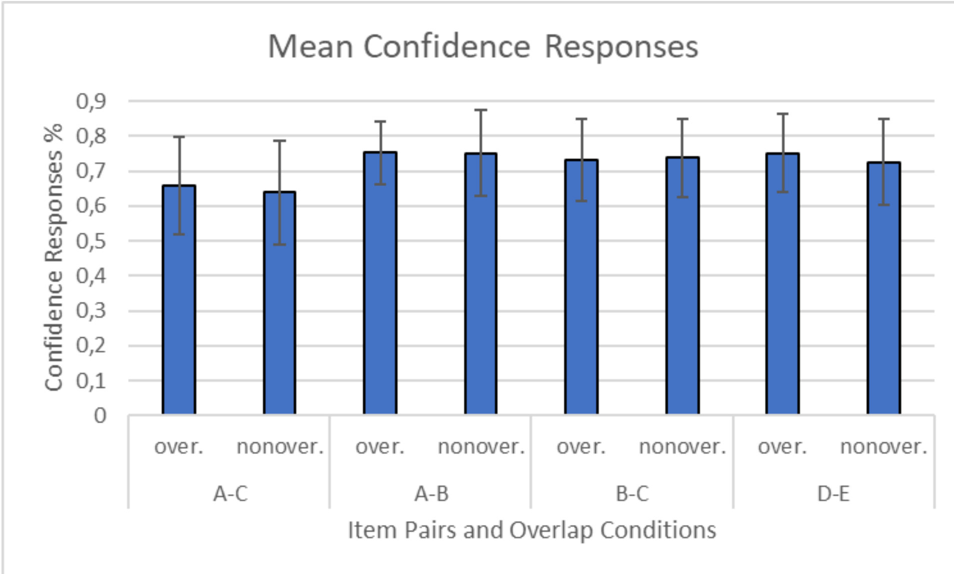

Figure 5. Displays the mean confidence percentage of correct choice responses for the sample pairs A-C, A-B, B-C and D-E with respect to their overlap (over.) and nonoverlap (nonover.) condition. The error bars represent the calculated standard deviation (+/-) for each pair and condition.

Discussion

The purpose of this study is to investigate the effect of context overlap on episodic memory integration. Based on previously known effects of context on memory, the hypothesis is that context overlap at encoding and retrieval would facilitate integration. Upon data calculation, the output showed no statistically significant effect of context overlap on memory integration. The alternative hypothesis is accepted.

Considered a fundamental frame and building block of episodic memories, the effect of visual contexts, have been subject to numerous studies. Found to facilitate correct episodic remembering with enhanced recollection (Bramao & Johansson, 2017; Bramao & Johansson, 2018), context and its effects on memory integration has yet not been investigated. Memory integration is argued to occur partly through the processes of inferential reasoning. We may make use of prior knowledge as a foundation to the newly added, by creating a partial overlap in the reoccurring experiences (Zeithamova, 2012). This process is argued to add to the flexibility and complexity in our behaviour (Schlichting & Preston, 2015; Backus et al., 2016). On a neural level, this has been argued possible through the overlap and interconnectivity of networks representing the two events (Moscovitch et al., 2016).

Through pervious research, the effects of context on episodic remembering have been realised. Alike, the underlying mechanisms that allow for memory integration have also been better understood. Yet, approaches to combine the effects of context and applying them to memory integration, have not yet been taken.

Thus, this study aims at investigating the process of memory integration in a real-world setting. Making use of immersive contexts through the use of VR, the aim is to mimic the detail rich surroundings in which one may find themselves in the real world. This allows for a more individual, free roaming encoding of features considered important as means to distinguish and remember, than what has been possible through 2D images and videos. The paradigm made use of to study such context effects, are based on the principle of E-R overlap, arguing that a contextual overlap between encoding and retrieval facilitates correct remembering. As a build upon this idea, are recent findings suggesting that is not merely the overlap between encoding and retrieval giving such effects. It is the presence of diagnostic features during retrieval that are the underlying reason (Bramao & Johansson, 2017). Due to its argued importance, both the E-R overlap idea and that of diagnostic value, are made use of in this paradigm.

Two *t*-tests and one eta squared were conducted to analyse the collected behavioural data. Represented by the A-C pairs, memory integration was measured. No statistically significant effect was found. Context overlap at the encoding and retrieval of the memories, did not facilitate their integration. This was found true for both the accuracy of target memory retrieval and the confidence associated with the answer given. Comparing these results to the literature is rather difficult, as no prior studies have done such investigations. Yet, based on investigation of the facilitating effects context has on remembering and what is known about memory integration, the findings of this study show to be contradictory to what may be expected.

Presented by the A-B pairs, direct association and encoding was measured. Comparing the overlap and nonoverlap condition with one another, no statistically significant results were found. As the A-B pairs at all times are presented simultaneously, and thus encoded in the same context, this result goes in line with what is expected. Supporting this finding, the confidence ratings showed no statistically significant difference between the overlap and nonoverlap condition, as well. As shown in previous studies, when two objects are presented at the same time and bound into the same context, the diagnostic features facilitate correct memory recollection (Bramao & Johansson, 2017; Bramao & Johansson, 2018).

Measuring the indirect association of the pairs, the encoding of the B-Cs, is also the site at which memory integration has been shown to occur. The B item which at a previous point had been directly associated with an A item, receives an additional object to pair with. As argued by the literature, in the process of encoding the B-C pair, subjects became aware of the overlapping B item. Through inferential reasoning guided by the instructions to be conscious of the overlap, an indirect association of the A-C items was expected to occur. This expectation has been based on the previous findings. An example of such study investigates this process through the decoding of functional magnetic resonance imaging (fMRI), in combination with a memory integrational task (Schlichting et al., 2014). In this study, subjects were to learn the association of a number of item pairs, in a similar A-B, B-C, design made use of in this study. At the time of test, the subjects were presented with 2 possible answers, from which they had to choose. The associations tested for where either direct (A-B, B-C) or indirect (A-C). Based on this design the function of area CA_1 in the hippocampus was highlighted. It was found that during encoding, the right signalling of CA_1, is associated with overlap of previously encountered information. Furthermore, as maintained by the idea of inferential reasoning, reinstated CA_1 signalling was found during trails in which correct integrational performance was shown. Comparing the expected results with the ones obtained, no statistically significant effect of E-R overlap on B-C association was found. This goes in line with the associated confidence results.

Taking note of the control items representing the site at which no memory integration was to occur, being the encoding of single associations of the D-E pairs, a statistically significant result with a large effect size was found. This goes in line with the findings of the literature on the facilitating effects that context overlap can have on remembering. Context overlap at E-R facilitates correct target memory recollection. As it has been shown previously, the sharing of the same context at both encoding and retrieval, facilitates correct recollection (Bramao & Johansson, 2018). Making use of a similar E-R overlap paradigm as this paper, Staudigl and

Hanslmayr, 2013 investigated the context dependency effect on an old/new recognition design. Investigating the integrational effect of context, subjects were asked to memorise a number of words presented atop movie clips. During the test phase, subjects were again to watch a number of words presented on movie clips. This time the subjects were asked to state whether the words shown were old or new. It was found that when a previously presented word was shown with the same movie clip, on which it had previously been encoded, subjects were significantly more likely to correctly report it as old or new. Supporting of the findings made in the literature, they found that during encoding, both the item words and contexts are bound together (Staudigl & Hanslmayr, 2013).

Yet, comparing the confidence ratings of the control pairs, no statistically significant difference was found. This may suggest that though context has been found to aid in the correct recollection of single association pairs, subjects did not experience any helping effects.

Limitations

Starting with the study design, some structural flaws may have limited the ability to truly explore the effect that a real-world setting may have on memory integration. Taking a total of one hour, its length is quite comparable to that found in previous studies and had been piloted on five subjects prior. Nevertheless, the duration and number of associations/encodings asked to make, may have shown too difficult. This may be found reflected in the overall low confidence ratings and accurate answers. Tying into the study design, the subject instructions may have confounded the context effect. Through the written instructions, the subjects had explicitly been made aware of that overlapping items were to be shown. They had also been made aware of the importance of this overlap, and that they were going to be tested on the indirect associations that the shared item allows for. Thus, instead of relying on the shared context, subjects may have ignored it, and in a more direct manner focused on creating these integrations. Yet, though this may be a possible factor, previous studies have used explicit instructions and found significant results (Backus et al., 2016). This may further support that the difficulty in task was too high.

A further limitation that may provide explanation as to why no significant effect was shown, may lie in the number of subjects made use of. When solely relying on behavioural data, the minimum number of subjects per condition suggested, is 30. Though all subjects are included in all conditions, the total number is below what is required. Thus, the possible effect of the real world setting on memory integration may not have been detected. Another reason as to why no effects have been shown, may lie in the context itself. As shown in previous studies, context merely facilitates to a certain extent. If the context was not diagnostic, it did not aid memory retrieval (Bramao and Johansson, 2017). Tying this to the difficulty of task, subjects may have not found use in having a context, whether it overlapped or not. Instead, being faced with such a demanding task, the immersive context may have added more additional information than what it was useful. This is rather difficult to compare to previous research as the way in which the context has been induced in this study is rather novel, and no other paper researched the effects of context on memory integration.

Improvements of this study may be found in an easier task and a more extensive piloting as well as change in instructions. To allow for the natural effect that context is argued to have on memory integration, the subjects may not be made aware of the indirect association of items.

Future Research

Future research may benefit to investigate the effect of context on memory integration further. More specifically, the possible effects of having an immersive real-world like setting. Reason for this lies in the yet unexplored effects that context may have on memory integration, as well as previous limitations to provide a naturalistic setting to study episodic memories in. Taking such approaches and further investigating such effects, may also highlight the possible differences and/or similarities between a real-world context on integration, and those presented on computer screens.

Conclusion

This study set out to investigate the possible integrational effects context may have on memory. Making use of an encoding-retrieval overlap/nonoverlap design, in combination with virtual environments, memory integration was studied. Upon the calculation of the data through the conduction of two *t*-tests, context did not show to facilitate memory integration. The alternative hypothesis (H_0) is accepted. Reason for the outcome results may be attributed to various factors. Such may include the study design, instructions given, number of subjects and possible context limitations. The approach of studying memory integration using context, and doing to in a real-world setting, may show to be insightful. Using context and real-world settings to study integration are both novel approaches and may lead to a better understanding of episodic memories. Thus, future research may benefit of making use of both context, and VR settings to further investigate their effects on memory integration.

References

Backus, A. R., Schoffelen, J. M., Szebényi, S., Hanslmayr, S., & Doeller, C. F. (2016). Hippocampal-Prefrontal Theta Oscillations Support Memory Integration. *Current Biology, 26*(4), 450–457. https://doi.org/10.1016/j.cub.2015.12.048

Bramao, I., & Johansson, M. (2017). Benefits and Costs of Context Reinstatement in Episodic Memory: An ERP study. *Journal of Cognitive Neuroscience, 29*(1), 52-64. DOI:10.1162/jocn_a_01035

Bramao, I., & Johansson, M. (2018). Neural Pattern Classification Tracks Transfer-Appropriate Processing in Episodic Memory. *eNeuro, 5*(4), ENEURO.0251-18.2018. https://doi.org/10.1523/ENEURO.0251-18.2018

Clayton, N., Salwiczek, L., & Dickinson, A. (2007). Episodic Memory. *Current Biology*, *17*(6), PR189-R191. https://doi.org/10.1016/j.cub.2007.01.011

Easton, A., Webster, L. A. D., & Eacott, M. J. (2012). The Episodic Nature of Episodic-Like Memories. *Learning & Memory, 19*(4), 146–150. DOI:10.1101/lm.025676.112

Henke, K., Reber, T., Duss, S. (2013) Integrating Events Across Levels of Consciousness. *Frontiers in Behavioral Neuroscience*, *7*(2013). DOI.org/10.3389/fnbeh.2013.00068

Hupbach, A., Gomez, R., Hardt, O., & Nadel, L. (2007). Reconsolidation of Episodic Memories: A Subtle Reminder Triggers Integration of New Information. *Learning & Memory*, *14*(1), 47–53. DOI: 10.1101/lm.365707

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source Monitoring. *Psychological Bulletin*, *114*(1), 3-28. http://dx.doi.org/10.1037/0033-2909.114.1.3

Mizumori., S. (2013). Context Prediction Analysis and Episodic Memory. *Frontiers in Behavioral Neuroscience*, *7*(2013). DOI: 10.3389/fnbeh.2013.00132

Moscovitch, M. (1995). Recovered Consciousness: A Hypothesis Concerning Modularity and Episodic Memory. *Journal of Clinical and Experimental Psychology*, 17(2), 276-90. DOI: 10.1080/01688639508405123

Moscovitch, M., Cabeza, R., Winocur, G., & Nadel, L. (2016). Episodic Memory and Beyond: The Hippocampus and Neocortex in Transformation. *Annual Review Of Psychology*, *67*, 105–134. DOI: 10.1146/annurev-psych-113011-143733

Nanay, B. (2018). Multimodal Mental Imagery. *Cortex, 46*(9), 1014. DOI: 10.1016/j.cortex.2017.07.006

Norman, K. A., & O'Reilly, R. C. (2003). Modeling Hippocampal and Neocortical Contributions to Recognition Memory: A Complementary-Learning-Systems Approach. *Psychological Review*, *110*(4), 611–646. DOI: 10.1037/0033-295X.110.4.611

Plancher, G., Gyselinck, V., & Piolino, P. (2018). The Integration of Realistic Episodic Memories Relies on Different Working Memory Processes: Evidence from Virtual Navigation. *Frontiers in Psychology*, *9*, 47. DOI: 10.3389/fpsyg.2018.00047

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the Neural Correlates of Implicit and Explicit Memory. *Nature, 392*, 595 598. DOI: 10.1038/33396

Schlichting, M. L., & Preston, A. R. (2015). Memory Integration: Neural Mechanisms and Implications for Behavior. *Current Opinion in Behavioral Sciences, 1*, 1–8. https://doi.org/10.1016/j.cobeha.2014.07.005

Schlichting, M. L., Zeithamova, D., & Preston, A. R. (2014). CA1 Subfield Contributions to Memory Integration and Inference. Hippocampus, 24(10), 1248–1260. https://doi.org/10.1002/hipo.22310

Spalding, K. N., Schlichting, M. L., Zeithamova, D., Preston, A. R., Tranel, D., Duff, M. C., & Warren, D. E. (2018). Ventromedial Prefrontal Cortex Is Necessary for Normal Associative Inference and Memory Integration. *Journal of Neuroscience, 38*(15), 3767 3775. https://doiorg.ludwig.lub.lu.se/10.1523/JNEUROSCI.2501-17.2018

Staudigl, T., & Hanslmayr, S. (2013). Theta Oscillations at Encoding Mediate the Context Dependent Nature of Human Episodic Memory. *Current Biology, 23*(12), 1101–1106. https://doi-org.ludwig.lub.lu.se/10.1016/j.cub.2013.04.074

Tonegawa, S., Pignatelli, M., Roy, D. S., & Ryan, T. J. (2015). Memory Engram Storage and Retrieval. *Current Opinion in Neurobiology, 35*, 101–109. https://doi.org/10.1016/j.conb.2015.07.009

Tulving, E. (1983). Ecphoric Processes in Episodic Memory. *Philosophical Transactions of the Royal Society of London B, 302*(1110), 361–371.

Tulving, E. (2002). Episodic Memory: From Mind to Brain. *Annual Review of Psychology, 53*(1), 1. https://doi-org.ludwig.lub.lu.se/10.1146/annurev.psych.53.100901.135114

Tulving, E., & Thomson, D. M. (1973). Encoding Specificity and Retrieval Processes in Episodic Memory. *Psychological Review, 80*, 352–373. http://dx.doi.org/10.1037/h0020071

Zeithamova, D., & Preston, A. R. (2010). Flexible Memories: Differential Roles for Medial Temporal Lobe and Prefrontal Cortex in Cross-Episode Binding. *The Journal Of Neuroscience, 30*(44), 14676–14684. DOI: 10.1523/JNEUROSCI.3250-10.2010

Zeithamova, D., Schlichting, M., & Preston, A. (2012). The Hippocampus and Inferential Reasoning: Building Memories to Navigate Future Decisions. *Frontiers in Human Neuroscience, 6*, 70. Doi: 10.3389/fnhum.2012.00070