Transcending Time and Space: A Holistic Exploration of the Mechanisms Underlying Autobiographical Memory Retrieval

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Out of the night that covers me,
Black as the pit from pole to pole,
I thank whatever gods may be,
For my unconquerable soul.

In the fell clutch of circumstance,
I have not winced nor cried aloud.
Under the bludgeonings of chance,
My head is bloody, but unbowed.

Beyond this place of wrath and tears,
Looms but the Horror of the shade.
And yet the menace of the years
Finds, and shall find me, unafraid.

It matters not how strait the gate,
How charged with punishments the scroll,
I am the master of my fate,
I am the captain of my soul.

– Invictus by W. E. Henley (1888)

Abstract

Autobiographical memories are memories one has of their life experiences. Although decades of research have provided insights into the mechanisms underlying memory retrieval from different perspectives (e.g., biological, cognitive, evolutionary, forensic, and clinical), there is still much about the retrieval process that is not well understood. The present thesis, therefore, aimed to bridge the gaps in the literature by examining autobiographical memory retrieval at both between-subjects and within-subjects levels.

Given the multidimensional nature of autobiographical memory, the second chapter of this thesis explored whether and to what extent the six aspects of memory (i.e., memory accuracy, memory specificity, recollective experience, memory functionality, rumination, and executive functioning) are related. In the first study, 53 pairs of monozygotic and 39 pairs of dizygotic twins watched a video of a simulated theft and later answered a recognition test measuring accuracy for items in the video. In between, participants retrieved 10 personal events with the help of cues and rated these memories on recollective experience. They also completed questionnaires measuring functionality and rumination, along with five tasks measuring the mental flexibility, visuospatial processing, inhibition, and the forward and backward verbal learning processes of executive functioning. Findings from Study 1 revealed that not all aspects of autobiographical memory are related. Whereas rumination and memory functionality were related, memory accuracy, memory specificity, recollective experience, and executive functioning appeared to function more independently.

To validate the findings of Study 1, a second study was conducted with a sample of 153 undergraduate students from the University of Nottingham Malaysia. Participants followed the exact same procedure as Study 1. Although the results of Study 2 largely resembled those of Study 1, Study 2 additionally found an association between recollective experience and memory functionality.

Using the data from Study 1 of Chapter 2, Chapter 3 of this thesis examined whether the six aspects of autobiographical memory are heritable. Because most of the correlations from Studies 1 and 2 were not significant, we conducted two exploratory factor analyses to determine whether there were underlying factor structures across the different aspects. The factor analyses revealed one new factor: working memory capacity (which is a combination of visuospatial processing and forward and backward verbal learning). Despite some reliability issues, findings from Chapter 3 revealed support for additive genetic contributions to rumination and working-memory capacity.

Whereas the previous chapters examined memory retrieval on a between-subjects level, Chapter 4 goes a level lower, and examines autobiographical memory retrieval on a more within-subjects level. Studies have shown that visual imagery and working memory are both important during the retrieval of autobiographical memories. However, their exact contributions during memory retrieval remains unclear. To address this gap in the literature, Chapter 4 compared the relative contributions of visual imagery and working memory during the retrieval of autobiographical memories using a dual-task paradigm. In the first study, 46 participants retrieved their autobiographical memories while following a moving dot, viewing a Dynamic Visual Noise (DVN), or viewing a blank screen. The memories retrieved were then rated on phenomenological properties, such as recollective experience, vantage perspective, emotional intensity, and emotional valence. Due to some technical and methodological limitations in Study 1, a follow-up study was conducted with 95 participants. Findings from both studies revealed that inhibiting visual imagery processing only delayed the memory retrieval process but did not affect the phenomenological quality of the memory retrieved. Furthermore, although taxing the working memory delayed the retrieval process, the phenomenological quality of the memories remained unaffected.

The findings of the current thesis highlight the importance of examining autobiographical memory more holistically. For instance, the associations between functionality and rumination, and between functionality and recollective experience, found in the present thesis suggest potential mechanisms that warrant further investigation. Furthermore, because the present thesis found support for the influence of additive genetics on the rumination and working memory capacity aspects of autobiographical memory, future studies should aim to identify the genes associated with these different aspects as this would deepen our understanding of the contributions of additive genetics and the environment on autobiographical memory retrieval. A better understanding of autobiographical memory retrieval would also aid clinicians in increasing the efficiency of the treatment of different clinical disorders, like depression and PTSD. This in turn, would help people develop healthier coping strategies, and lead better lives.

Keywords: Additive genetics, autobiographical memory, depression, heritability, PTSD, visual imagery, working memory.

Publication

The results of Study 2 of Chapter 4 have been published in the Quarterly Journal of Experimental Psychology (QJEP).

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"Ella Pugazhum Irraivanukke"

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Abbreviations

ACC	Anterior Cingulate Cortex
ADHD	Attention Deficit Hyperactivity Disorder
AI	Autobiographical Interview
AMI	Autobiographical Memory Interview
AMQ	Autobiographical Memory Questionnaire
AMT	Autobiographical Memory Test
AMT-AI	Autobiographical Memory Test – Alternating Instructions
ART	Autobiographical Recollection Test
BDI	Beck's Depression Inventory
BDNF	Brain Derived Neurotrophic Factor
BOLD	Blood Oxygenation Level Dependent
CAPS	Clinician Administered PTSD scale
CaR-FA-X	Capture and Rumination; Functional Avoidance; Executive Functioning
CBT	Cognitive Behavioural Therapy
CDI	Children's Depression Inventory
CES	Centrality of Event Scale
CSA	Childhood Sexual Abuse
DES	Dissociative Experiences Scale
DLPFC	Dorsolateral Prefrontal Cortex
DMN	Default Mode Network
DNA	Deoxyribonucleic Acid

DSM-IV	Diagnostic and Statistical Manual for Mental Disorders (Fourth Edition)
DSM-V	Diagnostic and Statistical Manual for Mental Disorders (Fifth Edition)
DVN	Dynamic Visual Noise
EMD-R	Eye Movement Desensitization Processing
FIA	Forgot-it-all-along
FMRI	Functional Magnetic Resonance Imaging
GWAS	Genome Wide Association Studies
HPRS	Hong Psychological Reactance Scale
HSAM	Highly Superior Autobiographical Memory
K-SADS-PL	Schedule for Affective Disorders and Schizophrenia for School-age Children – Present and Lifetime
MBCT	Mindfulness Based Cognitive Behavioural Therapy
MCQ	Memory Characteristics Questionnaire
mPFC	Medial Prefrontal Cortex
NMTR	Nottingham Malaysian Twin Registry
OGM	Overgeneral Memories
PCC	Posterior Cingulate Cortex
PDS	Posttraumatic Diagnostic Scale
PET	Positron Emission Tomography
PTSD	Post Traumatic Stress Disorder
RF-CBT	Rumination Focussed Cognitive Behavioural Therapy
RRS	Ruminative Response Scale

RST	Response Style Theory
SCID-IV	Structured Clinical Interview
SDAM	Severely Deficient Autobiographical Memory
SMS	Self-Memory System
TALE	Thinking About Life Experiences
TEMPau	Test Episodique de Mémoire du Passé Autobiographique
VMDA	Visual Memory Deficit Amnesia

Glossary

Allele – Alternate forms of a gene within a given locus

Aphantasia – A term that refers to the inability to form visual images in one's mind

Attention Deficit Hyperactivity Disorder – A common attention-deficit disorder that affects daily functioning and is characterized by patterns of inattention or hyperactivity (or impulsivity). Other symptoms include difficulties concentrating at school or work, difficulties following instructions, and more

Autobiographical memories – Memories that one has of his or her life experiences that can vary greatly in spatial, emotional, and temporal contexts

Autonoetic consciousness – A form of self-awareness which allows one to mentally travel in time to relive past experiences and imagine future events

Brooding – A repetitive and negative pattern of thinking where one engages in critical self-evaluation by comparing one's situation to some unachieved standard. This form of thinking is thought to be maladaptive.

Categoric memories – Memories for repeated events (or summaries of events) that lack specific details such as the time and place of occurrence

Complicated Grief Syndrome – Now formally recognised as Prolonged Grief Disorder, this disorder is characterized by symptoms of grief and intense yearning for a deceased person. Other symptoms include the preoccupation of thoughts related to the deceased person, emotional numbness, perception that life is meaningless, and more.

Depression – A mood disorder that typically occurs in adolescence and early adulthood and includes feelings of hopelessness, suicide ideation, diminished ability to concentrate, significant weight loss, and fatigue

Direct retrieval - An effortless process of retrieval in which cues directly activate representations in the autobiographical knowledge base, giving direct access to specific memories stored at the lower levels of the hierarchy

Directing behaviour – A core function of autobiographical memory which suggests that we use our memories to learn lessons from our past mistakes and to guide and present and future actions

Dizygotic twins – Also known as non-identical or fraternal twins, dizygotic twins are conceived by the fertilisation of two separate ova. Like regular siblings, dizygotic twins only share 50% of their DNA (as opposed to monozygotic twins who share 100% of their DNA)

Episodic memory – A system that stores memory for specific events

Executive functioning - A set of cognitive processes that enable planning, monitoring of goal-directed behaviour, inhibition of irrelevant stimuli, and more

Extended memories – Memories for events that last longer than a day

Flashbacks – Involuntary recollections of past traumatic events that are so vivid and emotionally intense that it makes a person feel as if they are re-experiencing their trauma in the present

Functional avoidance – Occurs when people avoid the retrieval of specific autobiographical memories as means of avoiding details that evoke negative emotions.

Gene – A basic unit of heredity that is passed from parent to child and contains genetic information necessary for the development and maintenance of a living organism

Generative retrieval – A slow and effortful process that begins at the top of the autobiographical knowledge base storing themes and lifetime periods and ends at the bottom of the hierarchy storing event-specific knowledge

Heritability – The proportion of phenotypic variation for a given trait that can be attributed to genetic factors

Inhibition – Refers to a set of cognitive processes that inhibit behaviours or prepotent responses

Intrusive memories – Memories for traumatic events that are remembered repetitively and involuntarily, often causing distress to the rememberer

Monozygotic twins – Better known as identical twins, monozygotic twins come from one fertilised ovum that splits into two zygotes. As a result, monozygotic twins share 100% of their genetic material.

Omissions – A common occurrence in memory research when participants are unable to recall a memory in response to a given cue

Overgeneral Memories (OGM) – Autobiographical memories that are not specific but are extended (events that last longer than a day) or categoric (repeated events) in nature

Posttraumatic Stress Disorder (PTSD) - A disorder induced by traumatic experiences, such as wars, natural disasters, accidents, or sexual violence. Some of the symptoms include flashbacks of the traumatic memory, distressing dreams related to the traumatic event, feelings of detachment, and more.

Recollective Experience – The subjective experience of mentally reliving an event in the past

Reflection – A more adaptive form of rumination where one engages in the neutral pondering of one's actions to alleviate depressive symptoms

Reminiscence bump – A tendency in people over 40 to recall autobiographical memories from their adolescence or early adulthood

Self-continuity – The third function of the tripartite model which suggest that we use our autobiographical memories to connect our past and present selves, ultimately forming a coherent self-identity

Self-Memory System model – A cognitive model of memory retrieval which suggests that our autobiographical memories are stored in a hierarchical structure with varying levels of specificity. The top of the hierarchy stores theme and lifetime periods, the intermediate level stores memories for general events, and the lowest level stores event-specific information

Semantic Association – A direct verbal association of the cue word. For example, the cue "happy" can prompt people to retrieve semantic associates such as "my dog"

Semantic memory – A system that stores information about oneself and the world

Social Bonding – A core function of autobiographical memory which suggests that we use our memories to develop and maintain intimacy in social relationships

Vantage perspective – Regarded as the point of view in which memories are remembered. Autobiographical memories are either remembered from a first-person perspective (viewed from the eyes of the rememberer) or a third-person perspective (viewed from a distance with the rememberer in the scene).

Working memory – A cognitive system with limited capacity that hold information when performing tasks.

Chapter 1: Autobiographical Memory

A Brief History of Autobiographical Memory

The history of autobiographical memory dates back to 330 B.C., when Aristotle examined the relationship between memory and the soul (Annas, 1995). In his seminal work *On Memory and Recollection*, Aristotle describes memories as records or reflections of one's past experiences. However, it was not until the 1800s that literature surrounding autobiographical memory began to emerge (Berntsen & Rubin, 2012). Sir Francis Galton was among the first to examine the retrieval of autobiographical memories in a systematic manner (Sotgiu, 2021). In 1879, while on a walk from the Athenaeum club to St. James' Street in Central London, Galton subjected himself to a visual exercise by focusing on the thoughts processes that had occurred during his walk. He details his findings in his paper (Galton, 1879a):

"I occupied myself during a walk, a distance of some 450 yards, in keeping a half glance on what went on in my mind, as I looked with intent scrutiny at the successive objects that caught my eye. The instant each new idea arose, it was absolutely dismissed, and another was allowed to occupy its place. I never permitted my mind to ramble into any bye-paths but strictly limited its work to the formation of nascent ideas in association with the several objects that I saw. The ideas were, therefore, too fleeting to leave more than vague impressions in my memory. Nevertheless, I retained enough of what had taken place to be amazed at the amount of work my brain had performed. I was aware that my mind had travelled, during that brief walk, in the most discursive manner throughout the experiences of my whole life; that it had entered as an habitual guest into numberless localities that it had certainly never visited under the light of full consciousness for many years; and, in short, I

inferred that my everyday brain work was incomparably more active, and that my ideas travelled far wider afield, than I had previously any distinct conception of."

In the weeks that followed, Galton had once again conducted his thought experiment and observed that many of his thoughts during the second attempt closely mirrored the first. To examine these mental associations more systematically, Galton developed a more rigorous method of observation by examining mental associations triggered by verbal cues. In his papers (1879a, 1879b), he describes carrying out what is now known as a cued-recall task (see the section on *Gathering Autobiographical Memories* for more details). Before the experiment began, he carefully selected 75 single-word cues (e.g., afternoon, abbey) and printed them on cards. During the experiment, he viewed the cues, one-by-one, and noted the first thought that came to mind. The experiment was repeated four times over the course of 4 months (75 words × 4 = 300 words), with a 1-month interval between each session. Not only did almost half of these cues (44%) elicit the same thoughts for two sessions or more, but the descriptions also contained experiences that were rich in sensorial information, such as taste, smell, vivid details, all of which are now known as the phenomenological properties of autobiographical memory (also see the contributions of Sigmund Freud and Victor and Catherine Henri to autobiographical memory in Sotgiu, 2021).

Although much of memory research at the time alluded to the existence of autobiographical memory, it was not until the late twentieth century that research on the subject took off (Brewer, 1986; Crovitz & Schiffman, 1974). The development of the field of autobiographical memory is widely attributed to David Rubin, a scholar from Duke University, who published the first edited book on autobiographical memory of the same name in 1986. At the time of publication, only twenty journal articles examining autobiographical memory were published (Berntsen & Rubin, 2012). Almost forty years later, the field of autobiographical memory has grown significantly, with a literature search of the keyword “autobiographical memory” in the Google Scholar and PsycInfo databases revealing over 5000 publications on the subject.

Autobiographical Memory, Forty Years Later

Autobiographical memories are memories we have of our past experiences (Rubin, 1986, 1996; Robinson, 1986). They can vary in spatial, emotional, and temporal context and can involve taste, smell, vision, hearing, touch, and more (Rubin, 2005). Like a time-machine that allows a traveller to go back in time, our memories make it possible for us to mentally re-experience events in our past, a term that was initially coined as *autonoetic consciousness* (Tulving, 1993). The autobiographical memory system can be classified into two distinct components: episodic and semantic memory (Tulving, 1972, 2002). Episodic memory allows us to remember events from a certain time with rich details (Conway, 2001; Rubin, 2005). The following is an example of an episodic memory from the current researcher, “Last Christmas Eve, my family binged the entire Lord of the Rings trilogy”. Semantic memory, on the other hand, refers to facts that we know about ourselves and the world, and these memories often lack spatial and temporal contexts (e.g., knowing the city we were born in, knowing the day we were born).

Our autobiographical memories are intricately linked to our self-concept as they define who we are over time and across contexts (Fivush, 2011; Hards et al., 2024). The interconnectedness between the self and autobiographical memories is best described in the Self-Memory System (SMS) model (Conway, 2005; Conway & Pleydell-Pearce, 2000). According to the SMS model, the retrieval of autobiographical memories occurs through the interaction of two key components: the working self and the long-term self. The working self is defined as a hierarchy of goals that “operate to constrain cognition, and ultimately behaviour, into effective ways of operating on the world” (Berntsen & Rubin, 2012; Conway, 2005; Conway et al., 2004). For example, students might want to become psychologists; to become a psychologist, they need a psychology degree; to obtain a psychology degree, they need to pass the exams; to pass the exams, they need to attend lectures.

The long-term self, on the other hand, consists of the conceptual self and the autobiographical knowledge base. The conceptual self is known as a set of self-structures that include one's values, beliefs, life scripts (i.e., knowledge about the timing of important life events that is shared in a specific culture), relational schema (i.e., how one perceives their relationship with others), and more (Berntsen & Rubin, 2012; Conway, 2005; Janssen & Haque, 2015). It includes information about who people were, who they are, and who they would like to become.

According to Conway and Pleydell-Pearce (2000), the autobiographical knowledge base organizes mental representations of our past experiences into three distinct levels. The highest level of the hierarchy stores lifetime periods, which are abstract time spans in an individual's life, ranging from several months ("Studying abroad for a semester") to several years ("When I completed PhD degree") (Sotgiu, 2021). Some common examples of themes that span different lifetime periods include school, work, family, etc. Once an overarching theme is accessed, search for a memory progresses to the second level of the hierarchy, which contains information for general events such as categoric memories (i.e., memories for repeated events) and extended memories (i.e., memories that last for an extended period of time). For instance, the lifetime period "When I completed my PhD" from the top of the hierarchy can activate general events in the middle-level, such as "Having meetings with my supervisor" or "Attending a conference overseas". The lowest level of the hierarchy, on the other hand, stores event-specific information, including details about the location, time, activities, and emotions associated with a particular event. For example, the general event "Attending a conference overseas" could activate event-specific memories such as

"Presenting my first paper to a room full of people and feeling extremely nervous" or "Feeling proud when my supervisor told me that I did a great job during my presentation".

Multidisciplinary Phenomenon

Although scientists have been examining what later would be called autobiographical memory for nearly 150 years, research into the phenomenon has grown exponentially in the last 40 years. What is most remarkable about this growth is the many perspectives that have been taken to study autobiographical memory, making it a truly multidisciplinary phenomenon.

However, these different perspectives have focused on different aspects of autobiographical memory. For example, researchers who take a biological perspective are preoccupied with the question of which neural substrates are involved when people encode and retrieve memories (Rubin, 2005, 2006). Researchers who take a cognitive perspective seem to focus on examining which event and memory characteristics and individual characteristics improve the encoding and retrieval of memories (Conway & Pleydell-Pearce, 2000; García-Bajos & Migueles, 2013; Le Port et al., 2012; Palombo et al., 2015). Meanwhile, researchers who take a social perspective often focus on collaborative remembering which occurs when people collectively recall shared experiences (Basden et al., 1997; Weldon & Bellinger, 1997). One commonly studied example of collective remembering is flashbulb memories (Brown & Kulik, 1977; Hirst & Phelps, 2016; Lanciano et al., 2024; Maswood et al., 2018), which are memories of one's circumstances when learning about an important or surprising public event (e.g., 9/11, COVID-19, the assassination of John F. Kennedy). Furthermore, researchers who adopt a developmental perspective often focus on the development of autobiographical memory across early childhood. A prominent focus in this area is childhood amnesia which is the inability to remember autobiographical memories from one's early childhood (Bauer, 2007, 2008; Bauer & Larkina, 2014; Rubin, 2000). Whereas researchers approaching autobiographical memory from an evolutionary perspective often examine how well people use their autobiographical memories to navigate daily life (Bluck et al., 2005; Bluck & Alea, 2011), those who take a forensic perspective tend to focus on whether people's recollections of past events are accurate (Loftus et al., 1987). Finally, those who examine autobiographical memory from a clinical perspective often focus on how rumination influences memory specificity, especially among individuals diagnosed with clinical disorders (Williams, 2006; Williams et al., 2007).

Although it has been fascinating to see this wide range of perspectives on autobiographical memory, these different fields do not connect well with other. Each field has its own approach and focuses on different aspects of autobiographical memory. This thesis, therefore, attempts to bridge the gaps between them by examining whether these different aspects of autobiographical memory are related. Whereas we were not able to include social and developmental perspective, we represented the cognitive perspective by measuring individual differences in participants' strength of recollective experience and executive functioning, the evolutionary perspective by measuring individual differences in participants' memory functions, the clinical perspective by measuring individual differences in the specificity of participants' memories and their tendency to ruminate, and the forensic perspective by measuring individual differences in memory accuracy. We also included the biological perspective by examining these individual differences in autobiographical memory by genetic factors.

Gathering Autobiographical Memories

There are several ways in which autobiographical memories can be elicited in the laboratory. One of the techniques introduced by Kopelman and colleagues (1989) is the

Autobiographical Memory Interview (AMI). The AMI is a structured interview designed to examine one's personal episodic and semantic memories across different lifetime periods (e.g., childhood to adolescence, early adulthood, and recent events). A typical AMI consists of two set of questions: a set of autobiographical incidents which prompts participants to retrieve specific memories (e.g., describing the first day at college), and a personal semantic memory set which prompts participants to recall personal semantic information (e.g., date of birth, location of birth, etc). The specificity of the memories provided are then rated by the experimenter on a scale of 0 to 3. A similar approach can also be observed in the Test Episodique de Mémoire du Passé autobiographique (or TEMPau) which assesses the specificity and detailedness of autobiographical memories in a controlled setting (Piolino et al., 2009).

Although the AMI distinguishes the episodic and semantic components of memory effectively, it does not adequately capture the qualitative detailedness of the memories retrieved. For instance, studies have shown that the AMI does not differentiate between memories that are described with rich detail with memories that merely contain enough information to obtain a full score (Barnabe et al., 2012). Moreover, because the AMI was initially developed to detect memory problems in amnesic patients, healthy controls tend to obtain maximum scores on the interview, leading to ceiling effects (Dritschel et al., 1992). To address these limitations, Levine et al. (2002) developed the Autobiographical Interview (AI), which closely resembles the AMI with a few key enhancements. In a typical AI, participants retrieve specific memories from five lifetime periods (e.g., early childhood, adolescence, early adulthood, middle-age, and recent events) as opposed to just three lifetime periods in the AMI. Furthermore, upon retrieving a memory, participants are prompted to recall additional sensorial, emotional, and perceptual details. These details are then categorised as either internal or external. Internal details refer to event-specific information, such as the time, place, and emotions experienced during the event, whereas external details refer to information unrelated to the event retrieved (Sheldon et al., 2018).

Structured interviews, like the AMI and AI, are effective at eliciting specific memories from different lifetime periods. However, it can sometimes be more useful to examine one's life narratives (Fromholt & Larsen, 1991). The life narrative method involves asking people to freely narrate important events that have happened in their life (Fromholt & Larsen, 1991; Fromholt et al., 2003). In their seminal study, Fromholt and Larsen (1991) asked patients with Alzheimer's disease and healthy controls to "tell about the events that have been important in your life". Participants were told that they would be given 15-minutes to provide their narration. These narratives were then transcribed and coded for several characteristics such as the number of memories, level of detail, number of transitional events, and more. One of the advantages of using the life narrative method is that it allows people to retrieve accessible memories across their lifespan without constraints (Rasmussen & Berntsen, 2023). However, the life narrative method has some limitations. For example, transcribing and coding the different narratives can be very labour-intensive.

Apart from the life narrative method, the nature of autobiographical memories can also be examined by asking people to recall important events that have happened in their life (Rubin & Schulkind, 1997; Thomsen & Berntsen, 2008). Some variations of this task include asking people for their most vivid memories, positive memories, negative memories, and more (Berntsen & Rubin, 2002; Cohen & Faulkner, 1988; Fitzgerald, 1988; Rubin & Berntsen, 2003). Upon describing the memory, the phenomenological qualities of the memory is rated on several scales. Another common approach of gathering autobiographical memories is through timeline studies where participants are asked to indicate on a timeline the important events that have occurred in their past (deVries & Watt, 1996; Schroots & Assink, 2005).

In addition, the autobiographical fluency task is a useful tool that assesses autobiographical memories across different lifetime periods (Conti et al., 2024; Dritschel et al., 1992). In this task, participants are given a limited amount of time (e.g., 90 seconds) to recall as many specific autobiographical memories from a certain lifetime period (i.e., adolescence). These descriptions do not need to be long. The procedure of retrieving specific memories is then repeated for different lifetime periods (e.g., childhood, early adulthood, middle-age) and the number of specific events is compared across these periods (Demiray et al., 2009).

The diary method, on the other hand, is commonly used to examine the accuracy of autobiographical remembering in the real world (Catal & Fitzgerald, 2004; Kristo et al., 2009; St. Jacques et al., 2011; Wagenaar, 1986). This method typically consists of a recording phase and a recall phase. At each phase, participants are usually asked to report details such as the description of the events, the characteristics of the memories, and more. The consistency between the different phases is used as a proxy for memory accuracy. Thompson (1982) carried out what is now known as the "roommate study" in which university students were asked to record events from their lives as well as from the lives of their roommate. The memorability of these different events was also rated. The roommates were not informed about the study until a week before the recall phase. Two weeks later, both students and their roommates were invited to the lab and were asked whether and how well they remembered the events that were recorded. Findings from Thompson's study revealed that events that were rated as memorable in the first session was also remembered better during the second session.

The diary method was also employed by St Jacques et al. (2011) who examined the effects of pictorial and verbal cues on autobiographical remembering in men and women. Participants in their study wore a SenseCam (similar to a GoPro), which periodically took pictures of their environment throughout the day. They also kept track of events during the day in a separate diary. After a delay, participants were asked to recall memories in response to photographs from the SenseCam or textual cues from their diaries. The memories were also rated on different memory characteristics such as recollective experience, vividness, emotionality, and uniqueness.

Although the diary method is effective for measuring real-world accuracy, participants in these studies may be biased in recording only certain memories. To overcome this limitation, Brewer (1988) introduced the experience sampling technique which requires participants to carry a beeper that would sound during random times in the day. When the beeper rings, participants record details such as the time, date, thoughts experienced, location of event, and more on a paper card. Among the advantages of using the experience sampling technique is that this method reduces any selection bias as people are asked to record random events throughout the day.

Another common method of gathering autobiographical memories in the laboratory is the Galton-Crovitz cueing method (Crovitz & Schiffman, 1974; Galton, 1879; Rubin, 1982). This method involves retrieving autobiographical memories in response to single-word cues (e.g., calm, happy, sad). A notable application of the Galton-Crovitz cueing technique is the Autobiographical Memory Test (AMT; Williams & Broadbent, 1986), in which participants retrieve specific memories in response to cues within 60 seconds. In addition to single-word cues, the AMT can also be adapted to target specific life events. For example, participants may be asked to retrieve their earliest memory (Peterson, 2021), their most important memory (Rubin & Schulkind, 1997), or a memory when they felt happy or sad (Anthony et al., 2024). The memories are then categorised into one of five groups: semantic associations (direct verbal associations of the cue), categoric events, extended events, specific events, and omissions (when participants are unable to recall a memory). Beyond textual cues, other types of stimuli, such as pictures and odours have also been used to elicit autobiographical memories in the laboratory (El Haj et al., 2020; Saive et al., 2014; Larsson & Willander, 2009).

Because the AMT helps elicit memories from different stages of life, this approach has provided insights into phenomena like the reminiscence bump (Janssen & Murre, 2008) which is a tendency to recall memories from one’s adolescence to early adulthood. Furthermore, the AMT has also been instrumental in identifying autobiographical memory dysfunction in people with clinical disorders, such as depression and Post-Traumatic Stress Disorder (PTSD; Williams, 2006; Williams & Broadbent, 1986; Williams et al., 2007).

Measuring Characteristics of Autobiographical Memory

When measuring the phenomenological properties of autobiographical memory, researchers tend to focus on three main aspects: the properties of the event, the properties of the memory, and participant-related measures (Fitzgerald & Lawrence, 1984; Irish et al., 2010; Nigro & Neisser, 1983; Rasmussen et al., 2015; Scoboria & Pascal, 2016; Talarico et al., 2004). Whereas the properties of events refer to objective details surrounding the event itself (e.g., age of the event, frequency of occurrence), the properties of memories refer to participants subjective experience during recall (e.g., recollective experience, belief in accuracy, vantage perspectives).

Among the tools used to examine the properties of events during retrieval is the Centrality of Event Scale (CES; Berntsen & Rubin, 2006, Yang et al., 2022), which measures how important an event is to a person’s identity and life story. There are two versions of the CES: The long version has 20 items (e.g., “This event has become a reference point for the way I understand myself and the world”), whereas the short version has seven items (e.g., “I feel that this event has become a central part of my life story"). Items on the CES are rated on a five-point Likert scale ranging from "totally disagree" to "totally agree".

The properties of memories, on the other hand, are commonly measured by tools such as the Memory Characteristics Questionnaire (MCQ; Johnson et al., 1988). This self-report tool measures various aspects of autobiographical memory such as recollective experience (e.g., "I remember how I felt at the time when the event took place"), emotional valence (e.g., "Feelings at the time were – positive or negative"), belief in accuracy (e.g., "Do you have any doubts about the accuracy of your memory for this event?") and more. The MCQ consists of 39 items, and each item is rated on a 7-point Likert scale.

Similar to the MCQ, the Autobiographical Memory Questionnaire (AMQ) is also a common tool used to measure different properties of autobiographical memory (AMQ; Rubin et al., 2003; Rubin et al., 2019). The AMQ has 21 items, and each item is rated on a 7-point Likert scale. Some of the aspects measured by the AMQ include reliving (e.g., "While remembering, it is as if I am living the occurrence again"), vividness (e.g., "While remembering, I can see everything in my mind."), belief in accuracy (e.g., "My memory of the event is an accurate reflection of the event as a neutral observer would report it and is not distorted by my beliefs, motives, and expectations."), field perspective (e.g., "While remembering, I see the memory from where I was during the event, that is, as if I was seeing it again from my own eyes at my original location"), observer perspective (e.g., "While remembering, I see the memory from a different location than the one I was at in the event, that is, as if I was remembering a new view of the same event as an outside observer."), emotional intensity (e.g., "While remembering, the emotions I feel are intense."), and emotional valence (e.g., "How positive or negative is this memory?").

Finally, participant-related measures such as the Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991) can also measure individual differences in autobiographical memory. For instance, the RRS is a self-report questionnaire which examines ruminative tendencies across individuals. The RRS has 22-items which measure brooding (e.g., “What am I doing to deserve this?”), depression (e.g., “Why can’t I get going?”), and reflection (e.g., “Analyse recent events to try to understand why you are depressed”) components of rumination. Each item is then rated on a 4-point Likert scale, ranging from 1 “never” to 4 “always” (see Materials section of Chapter 2 for more details). Higher scores on the RRS would therefore indicate higher ruminative tendencies, and lower scores on the RRS would indicate lower ruminative tendencies.

Memory Retrieval

Norman and Bobrow (1979) proposed that the retrieval of autobiographical memories involves three distinct processes. As reported by Conway and Pleydell-Pearce (2000), the first stage involves creating a cue for the memory search and deciding on the verification criteria which determines the appropriateness of the memory retrieved. In the second stage, the cue is matched to the memories stored. The third stage, on the other hand, involves verifying the appropriateness of the memory by determining whether the memory retrieved fits the search criteria. If the criteria are met, the memory search is considered successful. Otherwise, the three processes are repeated until the memory sought after is found.

Although Norman and Bobrow’s account provides a solid framework on the retrieval of autobiographical memories, it does not consider the complex nature of the autobiographical knowledge base. As previously discussed, the Self-Memory System model (Conway, 2005; Conway & Pleydell-Pearce, 2000) suggests that our autobiographical memories are stored hierarchically. The authors proposed that the retrieval of autobiographical memories occurs through one of two processes: direct retrieval or generative retrieval. Direct retrieval is known as an effortless process in which cues directly activate representations in the autobiographical knowledge base. Generative retrieval, on the other hand, is said to be a more effortful process of retrieval that begins at the top of the hierarchy and proceeds downwards to the bottom of the hierarchy. Memory searches can begin with lifetime periods (e.g., “When I was a graduate student”), move to the intermediate level storing general events (e.g., “When I spent two weeks in Japan”), and ultimately reach the lowest level of the hierarchy storing event-specific knowledge (“When I was stuck in a hotel for a whole day due to an impending typhoon”).

Evidence for the direct and generative retrieval of memories stems from a study by Haque and Conway (2001), who examined the construction of memories from the autobiographical knowledge base using the “probe” method. Across a series of experiments, participants retrieved specific memories in response to single-word cues. Approximately 2 seconds, 5 seconds, and 30 seconds after cue presentation, participants were presented with a probe which prompted them to either write (Experiment 1) or verbalise (Experiment 2) the contents of their thoughts. The reported memories were then classified into one of four categories: specific event, general event, lifetime period, or omission. The authors found that participants reported more lifetime periods at the 2-second interval, more general events at the 5-second interval, and more specific memories at the 30-second interval, suggesting that generative retrieval begins at the top of the hierarchy storing lifetime periods and ends at the bottom of the hierarchy storing event-specific knowledge. Some specific memories were also reported at the 2 second interval (direct retrieval), but they accounted for only 8 to 10% of the memories retrieved.

Although findings from Haque and Conway’s (2001) study suggest that direct retrieval is less common than generative retrieval, subsequent studies have shown that direct retrieval can be just as, if not more common, than generative retrieval (Barzykowski & Staugaard, 2016; Harris & Berntsen, 2019; Mace et al., 2021). For instance, Uzer et al. (2012)

examined the prevalence of directly retrieved memories in a memory cueing paradigm. Participants retrieved specific memories in response to cues related to objects or emotions and subsequently reported whether the memory came to mind immediately (direct retrieval) or they engaged in effortful search processes (generative retrieval). Participants reported that nearly 50% of their memories were retrieved using the direct retrieval strategy, further suggesting that this strategy may be more prevalent in everyday remembering than previously assumed.

More recently, however, Mace et al. (2017) proposed that the retrieval of autobiographical memories is not strictly linear and can involve multiple retrieval strategies. In addition to direct and generative retrieval approaches, people also use strategies, such as the repeating strategy (i.e., when a cue is continuously repeated until a memory comes to mind) and the temporal recall strategy (i.e., when temporal cues, such as the date, time, or season are used to retrieve memories). In their study, participants were required to retrieve a specific memory in response to eighteen phrases. Upon hearing the phrase, they were told to verbalise the content of their thoughts and describe the memory that came to mind. Whereas 57% of the memories were retrieved through direct retrieval, 12% to 15% of the memories were retrieved through generative, repeating, or temporal strategies. Only 1% of memories were retrieved using mixed strategies (also see Mace et al., 2021 for similar findings).

Accuracy of Autobiographical Memory

Whereas most research on autobiographical memory tends to focus on the phenomenological properties of autobiographical memory (McAdams & McLean, 2013; Rubin & Berntsen, 2003), research in domains such as eyewitness testimonies and recovered memories often focus on the accuracy of autobiographical memories or the accuracy of memory for prior remembering (Anthony & Janssen, 2024; Christianson, 1992; Loftus et al., 1987; Talarico et al., 2009).

Loftus and colleagues (1987), for instance, examined the influence of weapon focus on the accuracy of eyewitness testimonies. In their study, participants viewed a series of slides depicting customers in line at a fast-food taco restaurant. There were two experimental conditions. In the first condition, the second man in the queue handed over a check to the cashier who then returned the change. In the second condition, however, the man pulls a gun on the cashier which prompts said cashier to hand over money. The eye movements of the participants were recorded throughout the viewing session. Upon viewing the slides, participants were given a series of multiple-choice questions which tested their ability to remember details surrounding the event (e.g., the name of the restaurant, the object worn by a woman standing in the queue). They were also asked to identify the criminal from a lineup of twelve individuals and to rate their confidence in their selection. Loftus and colleagues revealed that people in the gun condition spent more time fixating on the gun compared to those who spent time looking at the cheque in the control condition. Those in the gun condition were also less accurate in identifying the perpetrator from the lineup, suggesting that the presence of a weapon can often result in the failure to recall details about the perpetrator (a phenomenon known as the “weapons focus effect”).

In the context of recovered memories, the accuracy of autobiographical remembering extends beyond the recollection of past events and includes memory for prior remembering (Arnold & Lindsay, 2002; Schooler et al., 1997). Whereas most people remember significant experiences easily, some people report having experiences of forgetting and subsequently recovering long-forgotten traumatic events. These memories often involve childhood sexual abuse (CSA). The veracity of recovered memories of CSA remains one of the most controversial research topics to date (Dodier, 2019; Otgaar et al., 2019), for some of these memories have been recovered in therapy during which highly suggestive techniques were employed (Dodier et al., 2019; Schooler et al., 1997). In such cases, patients claim to have recovered memories of abuse that remained forgotten or inaccessible for many years. However, evidence suggests that some victims who initially claimed to have recovered memories of CSA later retracted their claims, indicating that their allegations had been false (Ost, 2017).

Some memories of CSA are, however, recovered spontaneously and have similar rates of corroborating evidence as continuous memories of CSA – which are memories that were never forgotten (Geraerts et al., 2007). Schooler and colleagues (1997) described four case studies in which memories for CSA were recovered spontaneously. In each of these cases, the memories of the abuse were corroborated by independent sources. In two cases, although the victims reported recovered memory experiences (suggesting they had forgotten the events), they had talked about the abuse to a confidant during the period in which the memory of the abuse had been allegedly forgotten, suggesting the victims had not forgotten the abuse but the prior instance of remembering the abuse. The victims' underestimation of the prior knowledge of the experience was termed as the *forgot-it-all-along* (FIA) effect. Schooler and colleagues (1997) argued that the experience of recovering a memory at that moment may have been qualitatively different than that at the moments of prior remembering, in that the memory may have been recalled more thoroughly and involved greater emotion. The difference between the two instances of recollection (during recovery vs. prior remembering) may have led the victims to falsely believe that they had recalled the memory for the first time and that the memory had been inaccessible for many years.

Functions of Autobiographical Memory

Autobiographical memories are essential to everyday life as they serve a variety of functions (Bluck & Alea, 2002, Bluck, 2003, Bluck et al., 2005). The first function, known as the directive function, states that our memories serve as lessons that help guide our present and future actions. A personal experience that illustrates this function is as follows:

"When I was eleven, my family went on vacation to Perhentian Island, a beautiful island north of Peninsular Malaysia known for its crystal-clear waters and white sandy beaches. Because it was my first beach holiday, I would spend up to four hours a day swimming in the ocean. On one unfortunate day, while swimming in deeper waters, I failed to realise that the tide was coming in. Moments passed and it was not too long before I could no longer feel the ocean floor. I tried my best to swim back to shore, but the waves were too strong, and my arms grew tired. I tried to stay afloat for as long as I could, but before I knew it, I began to drown. Fortunately, there were two Australian divers who were returning from a dive. One of them rescued me and carried me back to shore."

When I think back to this event, I learnt that factors such as shifting tides and adverse weather conditions can often lead to fatal outcomes. This incident taught me to be more careful when swimming in deep waters and look for signs that are potentially life threatening. To further increase my preparedness, I enrolled myself in a three-year training program offered by the St John's Ambulance of Malaysia and became a qualified first aider.

The benefits of the directive function have also been observed in a laboratory setting (Waters et al., 2014). Kuwubara and Pillemer (2010) conducted a study that examined whether the directive function influenced donation behaviours in students from the University of New Hampshire. When the experiment began, participants were asked to think of a memory associated with their university. Students in the control group were not required to retrieve any memory. Upon memory retrieval, students rated their intention towards recommending the university to others, attending class reunions, donating money to the university, and more. Kuwubara and Pillemer showed that students who had retrieved positive memories were more likely to recommend their university to others, attend a class reunion, and donate money to the university. They were also more likely than controls to donate their money to their university than to a charity.

The second function, on the other hand, is known as the social or communication function (Waters et al., 2014). According to Bluck and Alea (2011), sharing autobiographical memories helps forge new relationships with strangers and strengthens existing relationships with partners, children, friends, or coworkers. Alea and Bluck (2007) were among the few researchers to examine the role of the social function in enhancing social relationships. Participants were required to retrieve specific memories of their partner and rate the changes in feelings of intimacy. The authors found that retrieving a memory often increased people's feelings of intimacy towards their partner. The third function is known as the self-function. The self-function of memory suggests that we use our memories to form a stable self-identity (Bluck, 2003; Conway, 2005). In other words, the self-function helps us decide who we are and whether we have changed or stayed the same over time.

Although autobiographical memory is known for its directing behaviour, social bonding, and self-continuity purposes, a fourth function of memory was recently established (Joorman & Siemer, 2004; Öner & Gülgöz, 2018; Pasupathi, 2003; Werner-Seidler & Moulds, 2014). The fourth function, known as emotion regulation, states that we use our memories to manage the way we feel about ourselves by enhancing positive emotions and supressing negative emotions (Sow et al., 2023). Wang and colleagues (2015) were among the many to support the four functions of memory. In their study, participants were required to complete a 13-item questionnaire which assessed their tendency to think about and share their memories. All thirteen statements measured the directive, social, self, and emotion regulation functions of memory. Findings from this study revealed that on top of using memories for directive, social bonding, and self-continuity purposes, people also used their memories to regulate the emotions. The authors reported that participants endorsed items related to emotion regulation such as “When a person is feeling bad, he/she thinks about things in the past in order to make him/herself feel better” and “When a person is feeling bad, he/she shares memories with others to make him/herself feel better”.

Autobiographical Memory in Clinical Disorders

Depression is a mood disorder that affects around 280 million people worldwide (World Health Organization, 2024). The disorder affects more women (6%) than men (4%) and has an average lifetime prevalence ranging from 6.5% to 21% (Bromet et al., 2011). There is evidence to suggest that the prevalence of depression differs between high-income countries and low-income countries, with lower income countries having lower depression estimates (Marx et al., 2023). According to the fifth edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-V), the diagnosis of depression requires five or more symptoms to be present within a 2-week period and one of the symptoms should be depressed mood and/or loss of interest in activities once enjoyed. Some symptoms of depression include feelings of hopelessness, suicide ideation, diminished ability to concentrate, significant weight loss, and fatigue. The onset of depression typically occurs in adolescence and early adulthood (Andrade et al., 2003; Kessler et al., 2005).

Depression has been linked with autobiographical memory. When asked to retrieve specific autobiographical memories (i.e., events that occurred at a certain time and place and lasted no longer than a day), people with depression tend to recall overgeneral memories (OGM) which are memories for events that are not specific but repeated or extended in nature (Liu et al., 2013; Williams et al., 2007). The OGM phenomenon was first discovered by

Williams and Broadbent in 1986. In their study, people with a history of suicide attempts were less likely to retrieve specific memories in response to cues compared to non-suicidal individuals. A more recent review by Williams et al. (2007) confirmed that OGM is highly characteristic in people with depression compared to healthy controls. Support for this notion stems from a study by Park et al. (2002) in which individuals with Major Depressive Disorder (MDD) and healthy controls were asked to recall specific memories in response to six positive and six negative cue words. Their findings revealed that people with MDD retrieved more categorical memories compared to the control group. Similar findings were also reported in Brewin et al. (1998), Kuyken and Dalgleish (1995), and Williams and Scott (1988).

Although more recent reviews have supported the notion that people with depression have difficulties remembering specific memories (Hallford et al., 2022; Hitchcock et al., 2014; Sumner et al., 2010), there are a few studies that offer mixed findings. Hitchcock et al. (2019) asked participants in the MDD and control groups to complete the Autobiographical Memory Test – Alternating Instructions (AMT-AI). During the AMT-AI, participants were required to retrieve specific memories in response to six cue words (AMT-S), categoric memories in response to six cue words (AMT-R), and to alternate between the recall of specific memories and general memories for 12 cue words (AMT-AI). Although participants in the MDD group recalled fewer specific memories in the AMT-S condition compared to the control group, they also experienced difficulties retrieving categoric memories in the AMT-R condition compared to the control group. Apart from having difficulties retrieving both specific and categorical memories on command, people with MDD also exhibited difficulties in switching between the retrieval of specific and categorical memories. Taken together, these findings suggest that difficulties in memory retrieval may extend beyond deficits in recalling specific memories.

There is evidence to suggest that OGM predicts the course of depression over time (Hallford et al., 2021; Sumner et al., 2010). In a meta-analysis, Sumner et al. (2010) examined the relationship between OGM and depressive symptoms at follow-up sessions. Their findings suggest that higher levels of overgeneral or categoric memories were correlated with higher levels of depressive symptoms at the follow-up sessions, ($r = .130$). Using a regression model, they further demonstrated that fewer specific memories ($\beta = -.170$) and more overgeneral or categoric memories ($\beta = .110$) significantly predicted higher levels of depressive symptoms at the follow-up session, even after considering baseline symptoms. The predictive relationship between OGM and the level of depressive symptoms at follow-up sessions was also reported to be stronger for clinical samples ($\beta = -.37$) than for healthy controls ($\beta = -.10$). These findings were further supported in a meta-analysis by Hallford et al. (2021) who also found a predictive relationship between OGM or categoric memories and higher levels of depressive symptoms at follow-up and between specific memories and lower levels of depressive symptoms at follow-up.

Furthermore, OGM also seems to persist in people with remitted depression (Park et al., 2002). Champagne and colleagues (2016) examined the relationship between OGM and remitted depression in adolescents aged 11 to 18. Using the Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997) as a measure of MDD diagnosis and the Children's Depression Inventory (CDI; Kovacs, 1981) as a measure of current depressive symptoms, participants were categorised into one of three groups: current MDD, remitted MDD, or no MDD (control). At the beginning of the experiment, participants were asked to complete an AMT where they were asked to retrieve specific memories in response to five positive (e.g., safe, surprised, happy, interested, and successful) and five negative cue words (e.g., hurt, lonely, sad, angry, and careless). The findings of Champagne et al. revealed that individuals with remitted depression retrieved fewer specific memories in response to both positive and negative cue words compared to the control group, indicating a potential risk for relapse (also see Hallford et al., 2022, for a meta-analysis).

Reduced autobiographical memory specificity is also a hallmark characteristic in other clinical disorders, such as posttraumatic stress disorder. Post-traumatic stress disorder, otherwise known as PTSD, refers to a disorder induced by traumatic experiences, such as wars, natural disasters, accidents, sexual violence, and more (World Health Organization, 2024). According to the DSM-V, symptoms of PTSD include flashbacks of the traumatic memory, distressing dreams related to the traumatic event, feelings of detachment, hypervigilance, sleep disturbances, difficulties concentrating, and more. Although most people will experience a traumatic event sometime or another in their lives, only 5.6% of people will go on to develop PTSD (Koenen et al., 2017). The prevalence of PTSD varies widely across countries, with higher rates (9.2%) observed in high-income countries, like Canada, and lower rates (1.7%) in lower income countries, like South Korea (Jeon et al., 2007; van Ameringen et al., 2008). Additionally, reports have also shown that women are twice as likely to develop PTSD than men (Tolin & Foa, 2006).

When examining the nature of traumatic memories in people with PTSD, victims often report experiencing flashbacks, which are involuntary recollections of the traumatic event (Andrews et al., 2000; Schooler et al., 1997). These intrusive memories tend to be extremely vivid and highly distressing (Brewin et al., 2012; Hellawell & Brewin, 2004). Studies have also shown that flashbacks lack a time perspective and are often experienced as if they are happening in the present (Brewin et al., 2010; Ehlers et al., 2004). Apart from traumatic memories, the retrieval of non-traumatic memories is also affected in people with PTSD (McNally et al., 1995). For instance, Kangas and colleagues (2005) examined the retrieval of autobiographical memories in recent survivors of head, neck, or lung cancer. In their first study, participants were asked to retrieve specific memories in response to ten positive (e.g., happy, brave, safe, strong, interested, important, successful, surprised, love, and special) and ten negative (e.g., lonely, doubt, hurt, strange, clumsy, tense, angry, sorry, fear, and stress) single-word cues. Although participants were explicitly instructed to retrieve specific memories, the cancer survivors retrieved fewer specific memories compared to the control group. The findings of Kangas et al. have also been reported in studies which examined the retrieval of memories in Vietnam War veterans and victims of motor vehicle accidents (McNally et al., 1995; Sutherland & Bryant, 2007).

Like depression, OGM is also a strong predictor of PTSD symptoms at follow-up sessions (Bryant et al., 2007). Bryant et al. conducted a longitudinal study on new recruits of the New South Wales Fire Brigade. At the beginning of the study, firefighter trainees completed the Structured Clinical Interview (SCID-IV; Spitzer et al., 1996) for the DSM-IV to assess their psychopathology. PTSD symptoms were measured using the Clinician Administered PTSD scale (CAPS; Blake et al., 1995). Because the firefighters were still attending classes and had not partaken in active duty, the PTSD symptoms measured served as baseline. Additionally, the trainees completed an AMT, where they retrieved specific memories in response to five positive and five negative cue words. Three years after commencing active duty, the firefighters were reassessed using the Posttraumatic Diagnostic Scale (PDS; Foa et al., 1997), but this time, the symptoms of PTSD reflected post-trauma experiences. A hierarchical regression model revealed that deficits in retrieving specific memories in response to positive cues before trauma exposure predicted PTSD symptoms after trauma exposure, suggesting that OGM may be an important risk factor for the development of PTSD (also see Harvey et al., 1998, for similar findings).

Cognitive Mechanisms Underlying OGM

The retrieval of OGM can be explained via the SMS model (Conway, 2005; Conway & Pleydell-Pearce, 2000; Sumner et al., 2012; Williams, 2006; Williams et al., 2007). According to this model, the search for specific memories begins at the top of the hierarchy, storing broad themes and lifetime periods; moves through the intermediate level storing general events; and ends at the lowest level storing event-specific knowledge. Williams et al. (2007) proposed that the retrieval of OGM occurs when the search processes for the memory sought after is interrupted at the intermediate level. For example, evidence for the early termination of memory retrieval in people with depression was demonstrated by Haque and colleagues (2014). When asked to retrieve specific autobiographical memories in response to fifteen cue words, depressed individuals retrieved more overgeneral memories (51%) compared to the healthy control group (33%). Whereas the control group was able to complete the search process from the top to the bottom of the hierarchy, the depressed individuals may have terminated their search process at the intermediate level storing general events.

The CaR-FA-X model is a prominent framework proposed to explain the OGM phenomenon (Williams, 2006; Williams et al., 2007). According to this model, there are three cognitive mechanisms that contribute to the development of OGM: capture and rumination (CaR), functional avoidance (FA), and impaired executive functioning (X). The first mechanism, known as capture and rumination, states that the search for specific memories in the knowledge base can be interrupted if self-relevant information is activated during the early stages of retrieval (Sumner et al., 2012; Williams et al., 2007). This self-relevant information can invoke rumination and truncate the search for specific memories (Stewart et al., 2018). According to the Response Style Theory (RST), rumination is defined as "repetitive and passive thinking about one's symptoms of depression and the possible causes and consequences of these symptoms" (Nolen-Hoeksema, 1991, 2003). If the search process is repeatedly interrupted at the intermediate level, general representations stored in this level may become increasingly elaborated, causing retrieval to move across the hierarchy rather than down the hierarchy (a phenomenon known as "mnemonic interlock"; Williams et al., 2007; Sumner et al., 2012). Future attempts at retrieval would therefore activate these elaborated general representations, resulting in the retrieval of OGM.

The second mechanism of the CaR-FA-X model, known as functional avoidance, occurs when individuals avoid remembering specific memories as a form of emotion regulation (Debeer et al., 2011; Sumner et al., 2012). According to Conway and Pleydell-Pearce (2000), recalling more general representations of trauma-related memories can reduce the emotional distress experienced by the rememberer. Although the strategy of remaining at the intermediate level may initially reduce negative emotions invoked by traumatic memories, this style of thinking can be generalized to other types of memories over time, including positive memories (Williams et al., 2007). As described by Stewart et al. (2017), people may develop a habit of retrieving OGM for everyday events as they may have learnt to associate the retrieval of specific memories with negative consequences, such as emotional distress. This avoidance strategy may explain why some people with depression and PTSD experience difficulties retrieving specific memories for non-trauma memories (Barry et al., 2018; Ono et al., 2016).

Besides functional avoidance, impaired executive functioning is also known as a strong contributor of OGM (Williams et al., 2007). Executive functioning refers to a set of cognitive processes that enable planning, monitoring of goal-directed behaviour, inhibition of irrelevant stimuli, and more (Dalgleish et al., 2007; Stewart et al., 2017; Sumner, 2012). In their seminal paper, Williams and colleagues (2007) detail that executive control plays a vital role during the search for specific memories in the autobiographical knowledge base.

Building on the work of Norman and Bobrow (1979) and Conway and Pleydell-Pearce (2000), they proposed that memory retrieval begins with the elaboration of a cue and the establishment of search criteria. The search for a specific memory then begins by activating themes and lifetime periods at the top of the hierarchy, followed by the activation of general events in the intermediate level, and, finally, event specific knowledge in the lowest level. Because the activation of a general event can result in the activation of many event-specific details, effective executive control is required to ensure that irrelevant information is inhibited during the search. These executive control processes also help supervise the retrieval process by matching the activated representation with the initial search criteria. Numerous studies have provided support for Williams et al.'s model as individuals with poor executive functioning have consistently exhibited difficulties retrieving specific memories (Piolino et al., 2010; Raes et al., 2010; Yanes et al., 2008).

Individual Differences in Autobiographical Memory

For decades, research on autobiographical memory has focussed on examining individual memories, such as important memories or traumatic memories, or categories of memories, such as whether positive memories are remembered better than negative memories, whether our memories feel more closer or distant from our present, whether our memories are retrieved from a first-person or third-person perspective, and more (Coleman et al., 2023; Janssen et al., 2022; Perl et al., 2023; Rice & Rubin, 2009; Robinson & Swanson, 1993; Schaefer & Phillipot, 2005). It was only recently that research examining individual differences in autobiographical memory began to emerge (Berntsen et al., 2019; Rubin et al., 2021; Rubin et al., 2003).

Because the previous section on autobiographical memory and depression already discussed individual differences in memory retrieval between those with and without depression, the present section will include studies that focus on individual differences in non-clinical populations. One of the earliest studies that examined these individual differences was conducted by Rubin et al. (2003). Over three experiments, participants retrieved autobiographical memories in response to either 15 or 30 single-word cues (e.g., candy, city, doctor, dress, horse, friend, health, etc.). These memories were then rated on different phenomenological properties, such as recollective experience, emotionality, belief in accuracy, visual imagery, and more. Participants also completed other measures, such as the Beck's Depression Inventory (BDI; Beck et al., 1961) which measured their depressive symptoms, the Dissociative Experiences Scale (DES; Read & Winograd, 1998) which measured dissociative experiences, and the Hong Psychological Reactance Scale (HPRS; Hong & Faedda, 1996) which measured psychological reactance. When examining the correlations between these measures, the authors found a correlation between the belief in accuracy of the memories retrieved and the scores on the BDI, $r = -.330$, and between the belief in accuracy of the memories retrieved and the scores on the DES, $r = -.300$, suggesting that some individual differences may be related. Similar findings were also reported by Rubin (2020a) who showed that scene (the ability to visualize spatial information such as the layout for any given memory) was highly correlated with other phenomenological characteristics, such as vividness, reliving, and belief.

Individual differences during memory retrieval have also been reported to be stable over time (Rubin et al., 2004). Rubin (2021) was among the few researchers to demonstrate this stability in autobiographical memory across two sessions. In the first session, participants retrieved specific memories in response to cues (e.g., an event "that was surprising or unexpected", an event "that changed your life", etc.) and subsequently rated them on different phenomenological properties, such as reliving, vividness, belief, visual, scene, content, specific time, auditory, coherence, centrality, rehearsal, and emotion. After a few weeks, participants retrieved and rated their memories again. However, the cues used to elicit autobiographical memories in the second session (e.g., an event "with a family member", an event "that involved something you were proud of", an event "that was expected") were different than the cues used in the first session. Findings from Rubin's study revealed that the correlations between the different properties remained highly similar across both sessions, even after the delay.

Although much research on individual differences in autobiographical memory have provided valuable insights, they possess several limitations. For instance, asking participants to retrieve specific memories and rate them on different phenomenological properties can introduce a selection bias, as participants may only recall memories that are important or emotionally salient (Gehrt et al., 2022). Moreover, biases introduced by one's culture (MacDonald et al., 2000; Wang et al., 2004) or gender (Ely & Ryan, 2008; Pillemer et al., 2003) may also impact the validity of these findings. To overcome these limitations, Berntsen et al. (2019) developed the Autobiographical Recollection Test (ART), a psychometric test designed to measure how well people remember events in their past. The ART measures seven phenomenological properties of autobiographical memory: vividness, rehearsal, reliving, visual imagery, scene, narrative coherence, and life-story relevance. Studies have shown that the ART has a high internal consistency (Billet et al., 2023; Gehrt et al., 2023). Furthermore, the validity of the ART was also examined in a series of studies by Gehrt and colleagues (2022). Participants began each study by completing the ART which consisted of 21 items. After completing a filler task, participants were given an AMT, where they retrieved specific memories in response to single-word cues. The phenomenological properties for each memory were rated using the AMQ (Rubin et al., 2003). All seven properties measured by the AMQ corresponded to the properties of the ART. Across three studies, Gehrt et al. showed that the properties of the ART highly correlated with the properties measured by the AMQ.

These results did not change when a 1-week delay was introduced between the ART and the memory retrieval task.

The Present Thesis

Based on the literature review, it is evident that autobiographical memory is a very complex construct with many dimensions. Although frameworks such as the SMS model and the CaR-FA-X model have advanced our understanding of the cognitive mechanisms underlying memory retrieval, no existing study has integrated these different perspectives. Therefore, the present thesis aims to bridge the gap in the literature by bringing together the different perspectives (i.e., biological, cognitive, evolutionary, forensic, and clinical) of autobiographical memory.

To achieve this goal, Chapter 2 of the present thesis examined whether and to what extent the six aspects (i.e., memory accuracy, memory specificity, recollective experience, memory functionality, rumination, and executive functioning) of autobiographical memory are related. In the first study, 53 pairs of monozygotic and 39 pairs of dizygotic twins (between the ages of 16 and 53 years) were recruited from the Nottingham Malaysian Twin Registry (NMTR). The data for this study was drawn from a larger twin study project, which in addition to examining the associations between the six aspects of memory, also aimed to assess the heritability of these six aspects (as discussed in Chapter 3). Although a convenience sample of students would have been sufficient to address the research question in this chapter, using the existing data from the twin study allowed us to maximise the value of the data collected. Furthermore, comparing the results from the twin study with those obtained from the sample of undergraduate students can help confirm the consistency of the findings across different groups and strengthen our conclusions. At the beginning of the experiment, participants watched a video of a simulated theft and later answered a 20-item recognition test that measured accuracy for items in the video. Recollective experience and specificity were assessed by asking participants to retrieve 10 personal events with the help of cue words and subsequently to rate these memories on recollective experience. The memories were later scored by the experimenters on specificity. Participants also completed two questionnaires: Thinking About Life Experiences (TALE) questionnaire, which measures functionality and has three subscales, and the Ruminative Response Scale (RRS), which measures rumination and also has three subscales. Finally, participants were given five executive functioning tasks: Berg's Card Sorting task (measuring task switching), Corsi Block task (measuring visuospatial memory), Flanker task (measuring inhibition), and Forward and Backward Digit Span tasks (both measuring verbal memory). The associations between the different aspects of autobiographical memory were estimated via a series of Pearson's correlation coefficients.

To validate the findings from Study 1, Study 2 of Chapter 2 was conducted with a sample of 153 undergraduate students from the University of Nottingham Malaysia, who were between 18 and 27 years old. These participants followed the exact same procedure as the twins from Study 1.

As mentioned previously, Chapter 3 of the present thesis examined the heritability of individual differences in autobiographical memory among Malaysian twins. The data for this study was taken from the first study of Chapter 2. Before estimating the heritability of the different aspects, two exploratory factor analyses were performed to identify potential underlying factor structures. The heritability of the different aspects of autobiographical memory was then measured by comparing the within-monozygotic and within-dizygotic twin pair correlations across the different tasks. Additionally, the influence of additive genetics, common environment, and unique environmental factors across the different aspects of memory were also estimated and discussed.

Whereas the previous two experimental chapters focussed on between-subjects differences in autobiographical memory, Chapter 4 laid more focus on the within-subjects differences observed during memory retrieval. For instance, studies have shown that visual imagery and working memory are both important to the memory retrieval process, but the exact contributions of these different components are unclear. To address this gap in the literature, Chapter 4 examined the relative contributions of visual imagery and working memory during memory retrieval using a dual-task paradigm.

In Study 1 of Chapter 4, participants retrieved specific autobiographical memories in response to six positive and six negative single-word cues while viewing either Dynamic Visual Noise (DVN), a moving-dot, or a blank screen (control). They then rated each memory on several phenomenological properties, such as the recollective experience, reliving, vantage perspective (first-person or third person), emotional valence, and emotional intensity of the memory. The specificity of the memories was scored by the experimenter once the experiment was over. A series of linear mixed models were fitted using R-Studio (Christensen, 2019) to compare the proportion of specific and non-specific memories, as well as the reaction times across the three conditions. Cumulative link mixed models were also fitted to compare the average ratings of the different phenomenological properties across the three conditions. Due to several methodological and technical issues, data collection for the first study ended abruptly. A follow-up study was then conducted with some modifications to the design of the experiment. For instance, instead of using the EyeLink 1000 plus system, the second study was conducted using EyeLink Portable Duo. Moreover, the parameters of the moving-dot condition were also made to be slightly more lenient. In addition to including the variable “vividness”, a secondary variable of “time” was included as a separate factor which compared the emotion at experience with emotion at the time of recollection.

The final chapter of this thesis synthesized the findings of the different chapters and discussed the contributions of the present thesis to the overall literature on autobiographical memory. Special attention will be given to the theoretical, legal, clinical, and methodological implications.

Chapter 2: Exploring the Associations Across Different Aspects of Autobiographical Memory

Autobiographical memories are memories that people have of their past experiences (Conway & Pleydell-Pearce, 2000; Robinson, 1986). They are known to serve a variety of different functions, such as guiding our present and future actions, developing and maintaining social relationships, shaping a stable self-identity, and emotion regulation (Bluck et al., 2005; Bluck & Alea, 2011; Öner & Gülgöz, 2018; Pillemer, 2009). Furthermore, studies have shown that autobiographical memories are complex as they contain multiple dimensions (Holland & Kensinger, 2010). For example, the following excerpt from Grysman et al. (2016) highlights the complex nature of autobiographical memory.

"This happened about 10–12 years ago but when I think about it the feelings are still strong today and I know this little event is what made me who I am today. I was never particularly interested in being a mother. I was not excited to find out I was pregnant and hated every aspect of the entire pregnancy. I just wasn't sure it was what I needed in my life at the time. My partner encouraged me constantly and talked positively of all the great experiences we would have but I still wasn't 100% convinced. When my son was born, I cried and loved him but it still didn't feel like he was mine. I felt no different, definitely not like a mom how I imagined I would. About 2 weeks after taking him home he was having trouble sleeping in his crib. I got up to get him, propped up some pillows for my back and half lay down with him on my chest. He fell asleep quickly with his hand tightly gripping one of my fingers. I instantly felt overcome with emotion. I felt happiness, calm and peace. I felt clarity, like this is who I am, this is where I'm supposed to be. I knew that my life had meaning."

Based on the above-mentioned narrative, it is evident that the author of the narrative not only recalled their memories but also, in a sense, mentally travelled back in time to re-experience the emotions that she felt before, during, and after her pregnancy. The author was also able to use her memory to pinpoint the exact moment she felt that she was a mother, which is a feature that defined her self-identity. Although features of memory such as memory functionality (Bluck et al., 2005), recollective experience (Tulving, 1985; Rubin, 2005), memory accuracy (Takarangi et al., 2006), rumination (Treynor et al., 2003), and more, have been well examined in autobiographical memory research, very little attention has been paid to understanding the individual differences across these dimensions (Berntsen et al., 2019; Palombo et al., 2018).

Furthermore, in Chapter 1, it was argued that autobiographical memory is often approached from different perspectives and each of these perspectives tend to focus on different aspects. For example, researchers who take a more clinical approach often focus on aspects such as rumination, memory specificity, and executive functioning (Williams, 2006; Williams et al., 2007). Researchers who take an evolutionary approach, on the other hand, tend to focus on memory functionality (Bluck et al., 2005). Researchers taking a more cognitive approach tend to focus on aspects such as memory specificity and recollective experience (Conway & Pleydell-Pearce, 2000). Although these different approaches have provided valuable insights into the mechanisms underlying memory retrieval, it remains unclear whether the different aspects of memory are related. To address this gap in the literature, we examined whether the individual differences that exist across six aspects of autobiographical memory (memory accuracy, memory specificity, recollective experience, rumination, memory functionality, and five executive functioning processes) were related.

Memory Retrieval

When examining the retrieval of autobiographical memories, people tend to retrieve a diverse array of mental representations for different life events, and these memories can range from important events (i.e., the birth of a child, weddings, or deaths of loved ones), to more mundane and trivial events that occur in everyday life, such as driving to work (Catal & Fitzgerald, 2004). These recollections are often reconstructed with information derived from an autobiographical knowledge base (Conway & Pleydell-Pearce, 2000; Conway, 2005). The Self-Memory System model proposed by Conway and Pleydell-Pearce (2000) suggests that our autobiographical memories are organised in a hierarchical knowledge structure which contains three levels. The first level comprises overarching themes such as relationships, work, and more, and within each theme are lifetime periods (e.g., middle school, high school, university, working at company X). The second level stores more general events, including repeated events (e.g., every Christmas) and extended events (e.g., summer camps). The third level of the hierarchy, however, stores event-specific knowledge. For example, information such as the time and place of occurrence and the sensorial and perceptual details for these general events can be found at this level.

The retrieval of specific autobiographical memories has been proposed to occur via the dual-process approach: direct and indirect (also called generative) processes (Conway, 2005; Conway & Pleydell-Pearce, 2000). During the generative retrieval of memories, which is a top-down process, individuals will first access themes and lifetime periods stored at the top of the hierarchy and then gradually descend to the bottom of the hierarchy, where general events and associated event-specific knowledge are stored (Conway & Rubin, 1993). The top level of the hierarchy is said to provide modes or cues to access the specific memories stored at the lower levels of the hierarchy (Williams, 1996). Direct retrieval, on the other hand, is said to be effortless and spontaneous process that allows direct access to specific memories stored at the lower levels of the hierarchy.

Studies have shown that individual differences exist during the retrieval of specific autobiographical memories (Sumner, 2012; Sumner et al., 2010). When asked to recall specific memories (i.e., memories for events that occurred at a particular time and place that lasted less than a day), people sometimes produce less specific or more overly general memories. For instance, the cue word “vacation” may prompt the general recollection “I enjoy going on a vacation” instead of the specific memory sought after, which is “My parents took me to Disneyland on my 9th birthday”. The difficulty in retrieving such specific memories is known as overgeneral memory (OGM; Williams & Broadbent, 1986). There is considerable evidence to suggest that individuals who suffer from clinical disorders, such as post-traumatic stress disorder (PTSD) and depression, exhibit more difficulties in recalling specific memories (Callahan et al., 2019; Williams et al., 2007), and that overgeneral memory can predict the prognosis and maintain the course of these disorders (Kleim & Ehlers, 2008; Raes et al., 2006).

Autobiographical Memory and Depression

Depression is a common mental disorder that has an average lifetime prevalence of 1–16.9% worldwide (Bromet et al., 2011). Some symptoms of depression include feelings of hopelessness, worthlessness, guilt, fatigue, loss of interest in activities once enjoyed, loss of appetite, and sleep disturbance (American Psychiatric Association, 2013). Numerous reviews have shown an association between overgeneral memory and depression (Hitchcock et al., 2014; Sumner et al., 2010; Williams et al., 2007). The primary tool used to assess overgeneral memory in many studies is the Autobiographical Memory Test (AMT; Williams & Broadbent, 1986). During a typical AMT, participants are required to retrieve specific memories that correspond to positive, negative, or neutral cue words. Despite explicit instructions to retrieve specific memories, the retrieval of fewer specific autobiographical memories during the AMT is characteristic in people with depression (Dalgleish et al., 2007; Williams et al., 2007).

When asked to retrieve a specific memory, depressed individuals often retrieve more overgeneral memories (e.g., "I enjoy the winter season" rather than "My family and I spent the last winter in Hawaii") than individuals without depression (e.g., Liu et al., 2013). These overgeneral memories can consist of either extended memories (i.e., events that lasted longer than a day such as a vacation) or categoric memories (e.g., "Times I fell off my bike") which are memories for repeated events (van Vreeswijk & de Wilde, 2004). For instance, Ricarte et al. (2011) examined the retrieval of autobiographical memories in depressed older adults and healthy controls of the same age. Participants completed both the Mini International Neuropsychiatric Interview (MINI) – which measured their depression symptoms – and the AMT. Despite instructions to retrieve specific memories, participants with depression retrieved more extended memories compared to the control group. Similar results have also been found for adolescents at risk for depression and people with remitted depression (Hallford et al., 2022; Kuyken & Dalgeish, 2011; Weiss-Cowie et al., 2023).

Other studies, however, have suggested difficulties in memory retrieval expands beyond specific memories and includes general memories as well (Dritschel et al., 2014; Hitchcock et al., 2019). For instance, Dritschel et al. (2014) tested people's ability to switch between the retrieval of specific and categorical memories using the Alternating Instructions version of the AMT task (AMT-AI) – where participants were required to retrieve both specific and categoric memories in an alternating manner. The authors reported that people with higher depressive symptoms retrieved fewer specific and categorical memories compared to people with lower depressive symptoms.

According to Williams et al. (2007), people develop OGM as means to avoid remembering details surrounding a negative event, but this more general retrieval style may apply towards the retrieval of memories for everyday events as well. Furthermore, although OGM may not be directly caused by depression, this generalized retrieval style can predict the onset of depression in some people (Hallford et al., 2021). For instance, Gibbs and Rude (2004) found that OGM following stressful life events predicted depression symptoms in a sample of healthy college students. Besides predicting the onset of depression, OGM is also known to predict the maintenance of the course of depression over time (Hallford et al., 2021; Sumner et al., 2010). Hermans and colleagues (2008), for example, showed that individuals with Major Depressive Disorder (MDD) who retrieved more categoric memories upon hospital admission were more likely to meet the criteria for MDD weeks later (also see Brittlebank et al., 1993).

Autobiographical Memory and Post-Traumatic Stress Disorder (PTSD)

Like depression, studies have also shown an overgeneral memory bias in individuals with Post-Traumatic Stress Disorder (PTSD; Moore & Zoellner, 2007; Williams et al., 2007). According to the American Psychiatric Association (2013), PTSD is a disorder that results from exposure to traumatic events, such as natural disasters, sexual violence, death of a loved one, war. People with PTSD often suffer from highly distressing intrusive thoughts and feelings related to a traumatic event.

When asked to retrieve specific memories for everyday events that were unrelated to their trauma, individuals with PTSD often retrieve fewer specific or more overgeneral memories compared to those without PTSD (Williams et al., 2007; Ono et al., 2016). McNally and colleagues (1995) were one of the pioneers who showed an association between overgeneral memory and PTSD. In their study, war veterans with PTSD were asked to retrieve specific memories in response to positive and negative cue words. Relative to veterans without PTSD, veterans with PTSD retrieved fewer specific memories in response to positive cues. In a more recent study, Schönfeld and Ehlers (2017) examined the recall of everyday memories in trauma survivors with and without PTSD in a diary study. Participants were required to record their autobiographical memories for a week. The specificity of the memories were later coded by the researchers. The authors found that the PTSD group recalled more overgeneral memories that was related to non-traumatic everyday events compared to the group without PTSD.

Apart from having an overgeneral memory bias, individuals with PTSD have also reported strong feelings of reliving when recalling traumatic memories (Brewin et al., 2010; Ehlers et al., 2004). When remembering their traumatic memories, people with PTSD often feel like they are re-experiencing the traumatic event as occurring in the present and this phenomenon is known as a flashback (Brewin & Holmes, 2003; Ehlers & Clark, 2000). Apart from experiencing these flashbacks, studies have found that highly accessible events, such as traumatic memories, may become a reference point for everyday life and can narrow a person's self-identity (Hellawell & Brewin, 2004; Kleim et al., 2013). Making traumatic memories central to their identity, in turn, can make it very difficult for people with PTSD to distance themselves from these negative experiences.

Finally, OGM has also been found to contribute to the development of PTSD (Brewin, 2014; Bryant et al., 2007). For instance, Harvey and colleagues (1998) examined whether overgenerality in acute stress disorder predicted the development of PTSD in survivors of motor vehicle accidents. They reported that the performance on the AMT predicted the development of PTSD at a 6-month post trauma, even after taking account the initial PTSD symptomatology.

The Underlying Mechanisms of Memory Retrieval

Given the effects of overgeneral memory on the psychological well-being of people with depression and PTSD, researchers have tried to better understand the factors that contribute to overgeneral memories. The CaR-FA-X model elaborates on the Self-Memory

System model by Conway and Pleydell-Pearce (2000) and is the most comprehensive model to date that has been put forward to explain the mechanisms underlying overgeneral memory (Williams, 2006; Williams et al., 2007). According to the CaR-FA-X model, three factors contribute to overgeneral memory: capture and rumination (CaR), functional avoidance (FA), and impaired executive function (X).

The capture and rumination mechanism posits that overgeneral memory interferes with the recollection of specific memories due to its relationship with rumination (Nolen-Hoeksema, 1991). Rumination is characterised by a pattern of repetitive negative thinking brought about by excessively focussing on negative events, and their causes and consequences (Nolen-Hoeksema et al. 2008). During the retrieval of autobiographical memories, capture and rumination occur when cues activate information about the self, which in turn, captures cognitive resources and aborts the search for memories at the intermediate level. If the search processes are interrupted at the intermediate level repeatedly, the result may be that during future retrieval attempts, the activation of the memories in the intermediate level will activate other intermediate level descriptions rather than specific memories (Williams, 1996, 2006). That is, when a cue is presented in the future, it is more likely to activate a memory search that moves across the hierarchy rather than down the hierarchy. This phenomenon is known as the mnemonic interlock. To put it succinctly, the repetitive and self-focussed processing style of rumination elaborates the information stored in the intermediate level of the autobiographical knowledge base. This elaboration, in turn, increases the likelihood of being captured and results in the retrieval of overgeneral memories.

The second component known to contribute to the retrieval of overgeneral memories is functional avoidance (Williams et al., 2007). Functional avoidance refers to the passive avoidance in retrieving specific memories as a means of avoiding the negative emotions surrounding a past trauma. During retrieval, the search for a specific memory is halted at the intermediate level of the hierarchy, as this activates memories that are less distressing than the memories stored in the lowest level of the hierarchy (Conway & Pleydell-Pearce, 2000). However, the passive avoidance of specific details during retrieval is reinforced in the long-run and is generalised to other types of events such as memories for mundane, everyday events and memories for important life events (Schönfeld et al., 2007). The association between overgeneral memory and functional avoidance has been found in those who experience bereavement (Neshat et al., 2013), sexual violence (Ogle et al., 2013), and family violence (Johnson et al., 2005). Schönfeld and Ehlers (2006) examined overgeneral memory in individuals with PTSD and found that higher levels of overgeneral memories were associated with avoidance strategies (e.g., thought suppression, avoidance of personal experiences, dissociation). Moreover, we can also find support for the functional avoidance mechanism in studies that have examined memory retrieval in individuals with complicated grief syndrome. Complicated grief syndrome is characterized by some symptoms of grief and persistent yearning which impairs a person's daily functioning (Prigerson et al., 2009). Individuals with complicated grief syndrome often find memories of their deceased loved ones to be highly distressing, similar to the nature of the trauma faced by individuals with PTSD. The researchers found that participants with complicated grief syndrome were more likely to use avoidance strategies when retrieving specific memories about their deceased loved ones, compared to individuals without complicated grief.

Impaired executive functioning (X) is the third mechanism in the CaR-FA-X model that has been proposed to contribute to the retrieval of overgeneral memories (Sumner, 2012; Williams et al, 2007). Working memory, inhibition, mental flexibility, and attentional control are just a few of the processes of executive functioning that collectively allow control over one's cognition and behaviour (Guler & Mackovichova, 2019). Deficits in executive functioning leads to a limited ability to conduct a successful search for memories in the hierarchy, resulting in the retrieval of overgeneral memories. Evidence for this mechanism stems from studies that show an association between higher levels of overgeneral memories and difficulties in different executive functioning processes (Sumner, 2012; Sumner et al. 2010). For instance, Raes and colleagues (2010) found an association between overgeneral memories and impaired inhibitory control in children. The researchers reported a significant correlation between overgeneral memories and lower scores on the Revised Early Adolescent Temperament Questionnaire which measured inhibition. A link between overgeneral memory and deficits in updating and maintaining information in the working memory via a running span performance task has also been reported in patients with frontotemporal dementia (Matuszewski et al., 2006). In addition, there is evidence to suggest that there are higher levels of overgeneral memories in individuals with a reduced working memory capacity (Yanes et al., 2008). For instance, Winthorpe and Rabbit (1988) reported that elderly participants with a reduced working memory capacity produced more overgeneral memories when they were required to complete a sentence span task during retrieval. Although most researchers have achieved a consensus on the CaR-FA-X model (Williams et al., 2007), autobiographical memory is a complex construct with multiple facets and is often measured on several dimensions. When examining autobiographical memory, one can measure the accuracy of a memory (memory accuracy), how specific it is (memory specificity), whether they are accompanied with a strong sense of reliving (recollective experience), and whether they serve a specific purpose (functionality). Given the complexity of autobiographical memory, more research needs to be carried out to better understand the mechanisms underlying memory retrieval.

Study 1

To treat people with depression and PTSD more effectively, it is important to thoroughly understand the fundamental processes underlying the retrieval of past personal experiences. Therefore, the objective of the present study was to examine the associations between six different aspects of autobiographical memory (i.e., memory accuracy, memory specificity, recollective experience, rumination, memory functionality, and executive functioning), by investigating whether and to what extent these different aspects are related.

A test battery comprising a range of subtests was administered to pairs of monozygotic and dizygotic twins. First, participants watched a video of staged burglary (Takarangi, Parker, & Garry, 2006). Next, participants were presented with 10 cue words and asked to provide a specific memory corresponding to each cue (which provides an estimate for memory specificity). They rated each memory on their recollective experience. Participants then proceeded to complete a 20-item recognition test about the mock burglary (which provides an estimate for memory accuracy). Upon completing the recognition test, they completed the Ruminative Response Scale (RRS) questionnaire, which measured rumination (Nolen-Hoeksema & Morrow, 1991), followed by the Thinking About Life Experiences (TALE) scale, which measured memory functionality (Bluck & Alea, 2011). Finally, the participants completed four executive functioning tasks (e.g., Flanker task which measures inhibitory control, Corsi-block task which measures visuospatial learning, Forward/Backward Digit Span task which measure verbal working memory, and Berg's Card Sorting task which measures mental flexibility). We selected these executive functioning processes as they have been implicated in autobiographical memory retrieval. For instance, studies have shown that individuals with higher inhibitory control, mental flexibility, and verbal working memory experience fewer difficulties in recalling specific memories compared to those with lower abilities in these domains (Guler & Mackovichova, 2019; Nieto et al., 2019). Furthermore, there is also evidence to suggest that visuospatial processing and memory accuracy are related (Janssen et al., 2015).

Based on the literature, we developed the following hypothesis: Because studies have shown that rumination and executive functioning are related to overgeneral memory (Sumner, 2012; Williams et al., 2007), we expect to find a correlation between three components of autobiographical memory, which are executive functioning, rumination, and memory specificity. It is possible that individuals with better executive functioning and lower levels of rumination may have better memory specificity. However, there were no predictions about the associations of other components of autobiographical memory.

Method

Participants

The data used in the present study formed part of a larger twin project, which in addition to examining the heritability of autobiographical memory (see Chapter 3) also examined the associations between the six aspects of memory. Using this dataset therefore allowed us to maximise its value. The present study was advertised via social media (i.e., Facebook, Twitter, Instagram) and traditional media (i.e., newspaper advertisements, radio talk shows). Because we could not conduct an a priori power analysis for a twin study design, we initially aimed to recruit 100 pairs of monozygotic and 100 pairs of dizygotic twins. However, we were unable to meet this target due to recruitment challenges related to the COVID-19 pandemic. As a result, 69 pairs of monozygotic twins and 53 pairs of dizygotic twins were tested across two cohorts via the volunteer sampling method from the Nottingham Malaysian Twin Registry (NMTR). Although data collection for the first 20 pairs of twins was conducted face-to-face, the advent of the pandemic rendered it impossible to continue in-person data collection. Data collection for the first study was therefore, resumed online. Pairs of participants were required to join a Google Meet session, where they would be briefed about the study and would eventually complete the experiment.

Because a member from a pair of monozygotic twins had a learning disability, their datasets were removed from the analyses. The datasets from two pairs of monozygotic twins and one pair of dizygotic twins were also excluded because the program running the executive functioning tasks crashed during the completion of the experiment. Another three pairs of monozygotic twins and four pairs of dizygotic twins were removed because at least one of them obtained a score of 10 (or less) out of 20 for the recognition task. Furthermore, we removed the data from three pairs of monozygotic twins because at least one of them achieved an overall accuracy of less than 25% for the Flanker task. Another two pairs of monozygotic twins were removed because at least one of them obtained a very low score (i.e., 1 out of 9) for the Corsi Block task. Two pairs of monozygotic and three pairs of dizygotic twins were also excluded because at least one of them achieved an accuracy of less than 20% (i.e., 2 out of 10) on the digit span task. In addition, two pairs of monozygotic twins and one pair of dizygotic twins were excluded as they obtained a perseverative response rate of 0% on the Berg's Card Sorting task. We also removed two pairs of dizygotic twins because at least one of them were clinically diagnosed with Attention Deficit Hyperactive Disorder (ADHD). Moreover, the datasets of a pair dizygotic twins were excluded for one of them was diagnosed with Major Depressive Disorder (MDD). Moreover, a pair of dizygotic twins were excluded because they were raised by separate families. Finally, we removed the datasets of one pair of monozygotic and one pair of dizygotic twins from the analyses because they completed the experiment twice.

The final sample comprised of 184 participants (47 males and 137 females), who were between the ages of 16 and 53 years (*M* = 25.54*, SD* = 6.74). The zygosity of the twins was determined through a self-report demographics survey that all participants completed before the study began. The present study was approved by the Science and Engineering Research Ethics Committee (SEREC) of the University of Nottingham Malaysia (AFCM210319).

Materials

Movie. In the present study, we used a video depicting a mock burglary created by Takarangi et al. (2006) and previously used in other eyewitness memory studies (e.g., Ito et al., 2019; Otgaar et al., 2014; 2016). The YouTube video shows an electrician named 'Eric' who steals some belongings from his client's home while working on several electrical jobs. There are two versions of the movie, which are identical except for eight critical details: the logo on Eric's van, the bed Eric passed, the soft drink Eric took from the refrigerator, the colour of the baseball cap Eric wore, the magazine Eric read, the colour of the mug in the kitchen, the picture of the landmark hanging on the wall, and the device Eric used to check the time. Whereas one twin of the pair watches one version of the video, the other twin watches the other. The video does not contain any audio and lasts for a duration of 6 minutes and 44 seconds.

Autobiographical Memory Test (AMT). In the present study, memory specificity was assessed using the Autobiographical Memory Test (AMT; Williams & Broadbent, 1986), in which participants retrieved specific memories in response to five emotional (i.e., sad, angry, love, happy, and fear) and five neutral cue words (i.e., river, fire, book, city, and flower). The cue words were adapted from Maki et al. (2013) and Talarico et al. (2004). A combination of emotional and neutral cues was used as previous research has shown that words from these categories are known to elicit memories with different temporal distributions. For instance, Robinson (1976) showed that emotional cues tend to elicit more recent memories compared to neutral cues. Furthermore, there is also evidence to suggest that emotional cues tend to produce memories rated higher in reliving and belief in accuracy compared to memories elicited by neutral cues (Maki et al., 2013). Given these differences, a mix of neutral and emotional cue words were used in the present study to ensure that a broader and more representative sample of autobiographical memories was obtained.

Recognition Task. To assess the accuracy for items in the video, a two-alternative forced-choice test was administered (Takarangi et al., 2006). The test included twenty short statements describing items or events from the video. At the beginning of the task, participants were told that they would be answering a series of questions for the video they watched and that each question would have two parts: the first part requires them to select the appropriate answer for each item, and the second part involves rating the confidence in their answer.

Before the task began, participants were given an example question that read, "Eric was working in a ___". They were then given two options to choose from: "a house" or "a shop". After selecting an option, they rated the confidence in their answer on a 5-point Likert scale ranging from 1 "not at all confident" to 5 "very confident". Following the sample question, participants proceeded to answer the 20-item test. At the end of the test, participants were given a score out of 20 as a measure of their memory accuracy. The full list of items, along with their options, are included in Table 2.1.

Table 2.1

All 20-items presented in the recognition task that assessed accuracy for items in the video.

Items	Options
Eric was wearing ___	overalls or jeans
Eric ate ___	an apple or a banana
The magazine that eric read was ___	Time or Newsweek
Eric read the note from the homeowner in the ___	kitchen or hallway

The tool that Eric used in the kitchen was ___	pliers or a screwdriver
In the lounge, the picture Eric looked at was the ___ Tower	Eiffel or Leaning
The bed in the first bedroom was ___	made or unmade
In the second bedroom, Eric tested a ___	power point or light fitting
Eric played a ___	Video or CD
In the second bedroom, Eric tried on a ___ cap	red or black
The name of Eric's company was ___	AJ's Electricians or RJ's Electricians
Eric checked the time ___	on his watch or on the wall clock
The jewellery that Eric stole in the first bedroom was ___	earrings or a necklace
In the lounge, Eric looked through a ___	journal or photo album
Eric's van was ___	blue or red
Eric found the house key under a ___	door mat or flower pot
Eric rummaged through papers that were next to a ___ mug	green or white
Eric drank a can of ___	Coke or Pepsi
In the bathroom, Eric stole ___	pills or perfume
Eric stole ___ in the second bedroom	money or a ring

The Thinking About Life Experiences (TALE) Scale. The Thinking About Life Experiences (TALE) scale is a questionnaire designed to assess the directive, social bonding, and self-continuity functions of autobiographical memory (Bluck & Alea, 2011; Bluck et al., 2005). The scale has 15 items which are distributed across these three functions. For the self-continuity function, three items measured whether people reflect on their memories to think about how much they have changed or stayed the same over time; two items measured how much one's belief or values have evolved. Concerning the social bonding function, three items examined whether people use their memories to develop intimacy in social relationships; two items measured whether people use their memories to maintain their relationships. Finally, all five items measuring the directive function explored whether and to what extent people use their memories to learn from their past behaviours to guide their actions (see Table 2.2).

At the beginning of the questionnaire, participants were presented with the following instructions for completion: "Sometimes people think back over their life or talk to other people about their life: it may be about things that happened quite a long time ago or more recently. We are not interested in your memory for a particular event, but more generally in how you bring together and connect the different events and periods of your life" (Bluck & Alea, 2011). Upon reading the instructions, participants completed two baseline items that assessed their overall tendency to think back on or talk about their lives: "In general, how often do you think back over your life?" and "In general, how often do you talk to others about what's happened in your life?". Responses were made on a 5-point Likert scale, ranging from 1 "almost never" to 5 "very frequently".

Following the baseline items, participants completed all 15-items from the questionnaire. The stem statement for each item was "I think back over or talk about my life or certain periods of my life ...". A total score ranging from 15 to 45 was given at the end of the questionnaire.

In Chapter 1, it was proposed that autobiographical memory has four main functions: directive, social bonding, self-continuity, and emotion regulation. However, the present study only focussed on the three functions assessed by the TALE. Emotion regulation was not measured because a psychometric tool that assesses all four functions of memory in a single scale remains to be developed. Furthermore, the TALE was selected because it has been demonstrated to be valid and reliable across different cultural contexts. For example, its reliability has been confirmed in Japanese (Maki et al., 2015), Trinidadian (Alea & Ali, 2018), and European samples (Harris et al., 2014; Wolf & Zimprich, 2015). Maki and colleagues (2014) further reported that the TALE exhibits strong internal reliability and validity (α = 0.76 – 0.84). Additionally, all three subscales of the TALE have been found to possess high internal consistencies (Bluck & Alea, 2011; Vranić et al., 2018).

Table 2.2

The 15 items in the TALE questionnaire and their respective functions.

Functions	Items
Self	When I want to feel that I am the same person that I was before
	When I am concerned about whether I am still the same type of person that I was earlier
	When I am concerned about whether my values have changed over time
	When I am concerned about whether my beliefs have changed over time
	When I want to understand how I have changed from who I was before
Social	When I hope to also find out what another person is like
	When I want to develop more intimacy in a relationship
	When I want to develop a closer relationship with someone
	When I want to maintain a friendship by sharing memories with friends
	When I hope to also learn more about another person's life
Directive	When I want to remember something that someone else said or did that might help me now
	When I believe that thinking about the past can help guide my future
	When I want to try to learn from my past mistakes
	When I need to make a life choice and I am uncertain which path to take
	When I want to remember a lesson I learned in the past

Ruminative Response Scale (RRS). The Ruminative Response Scale (RRS) was developed by Nolen-Hoeksema and Morrow (1991) as a self-report measure of rumination (Nolen-Hoeksema et al., 2008; Treynor et al., 2003). The questionnaire consists of 22 items (see Table 2.3) that measure the three different components of rumination. Eleven items on the scale assess brooding (i.e., a maladaptive form of rumination where one engages in critical self-evaluation by comparing one's situation to some non-idealistic standard), five items that assess reflection (i.e., a neutral pondering of one's past actions to alleviate depressive symptoms), and six items which measure the depression domain (Treynor et al., 2003; Schoofs et al., 2010). The items in the brooding and depression subscale begins with the stem statement "Think…", whereas the items in the reflection subscale do not begin with a stem. Each item on the scale is rated on a 4-point Likert scale, ranging from 1 "never" to 4 "always".

At the beginning of the questionnaire, participants were presented with a set of instructions, "People think and do many different things when they feel sad, blue, or depressed. Here is a list of possibilities. Please tell me if you never, sometimes, often, or always think or do each one when you feel down, sad, or depressed. Please indicate what you generally do, not what you think you should do" (Treynor et al., 2003). The total score of the RRS ranges from 22 to 88, with lower scores indicating lower levels of rumination.

The validity and reliability of the RRS have been demonstrated across different cultures. For instance, its reliability has been found in European (Extremera & Fernández-Berrocal, 2006; Griffith & Raes, 2014; Parola et al., 2017), North and South American (Lucena-Santos et al., 2018; Whisman et al., 2020), East Asian (Hasegawa et al., 2013; Lee & Kim, 2014), and in clinical and non-clinical samples (Schoofs et al., 2010). In addition to strong test-retest reliability, the RRS scale is also noted for its high internal consistency (Luminet, 2004; Nolen-Hoeksema & Morrow, 1991).

Table 2.3

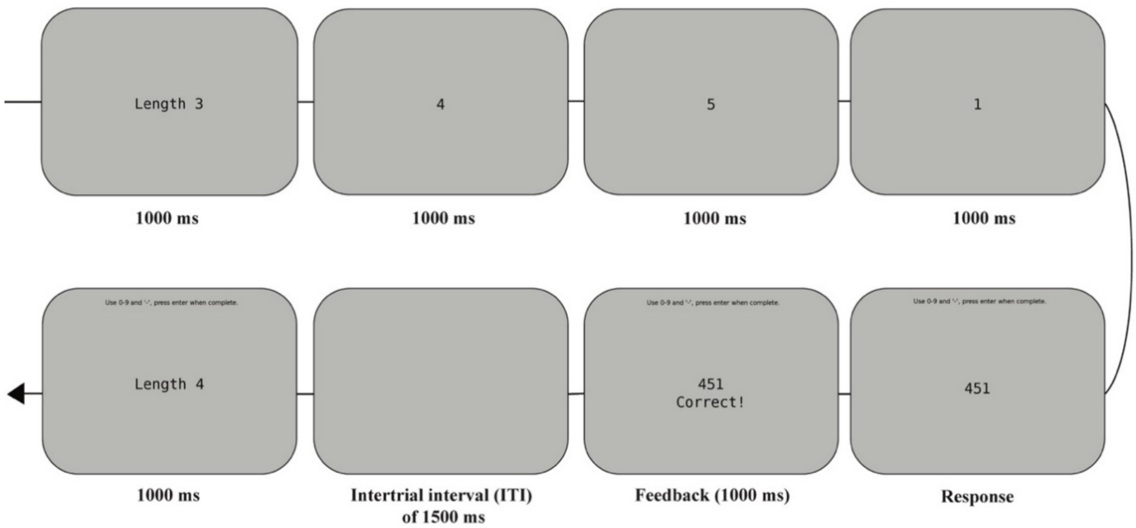
All 22 items presented in the Ruminative Response Scale (RRS) questionnaire

Subscale	Items
Brooding	Think “What am I doing to deserve this?”
	Think “Why do I always react this way?”
	Think about a recent situation, wishing it had gone better
	Think “Why do I have problems other people don’t have?”
	Think “Why can’t I handle things better?”
Reflection	Analyse recent events to try to understand why you are depressed
	Go away by yourself and think about why you feel this way
	Write down what you are thinking and analyse it
	Analyse your personality to try to understand why you are depressed
	Go someplace alone to think about your feelings
Depression-related	Think about how alone you feel
	Think “I won’t be able to do my job if I don’t snap out of this”
	Think about your feelings of fatigue and achiness
	Think about how hard it is to concentrate
	Think about how passive and unmotivated you feel
	Think about how you don’t seem to feel anything anymore
	Think “Why can’t I get going?”
	Think “I won’t be able to concentrate if I keep felling this way”
	Think about how sad you feel
	Think about all your shortcomings, failings, faults, and mistakes
	Think about how you don’t feel up to do anything
	Think about how angry you are with yourself

Digit Span task. The Digit Span task is a subtest of the Wechsler intelligence scale and is often used to measure an individual's verbal working memory (Orsini et al., 1987; Wechsler, 2008). In a typical Digit Span task, an individual is presented with a series of digits and is subsequently required to recall the digits in the correct order (see Figure 2.1). The test consists of a forward condition (where participants are required to remember the order of the digits as they were presented) and a backward condition (where participants are required to remember the digits in a reversed order). An individual's digit span is calculated as the longest length of digits correctly recalled, with a final score ranging from 0 to 10.

Figure 2.1

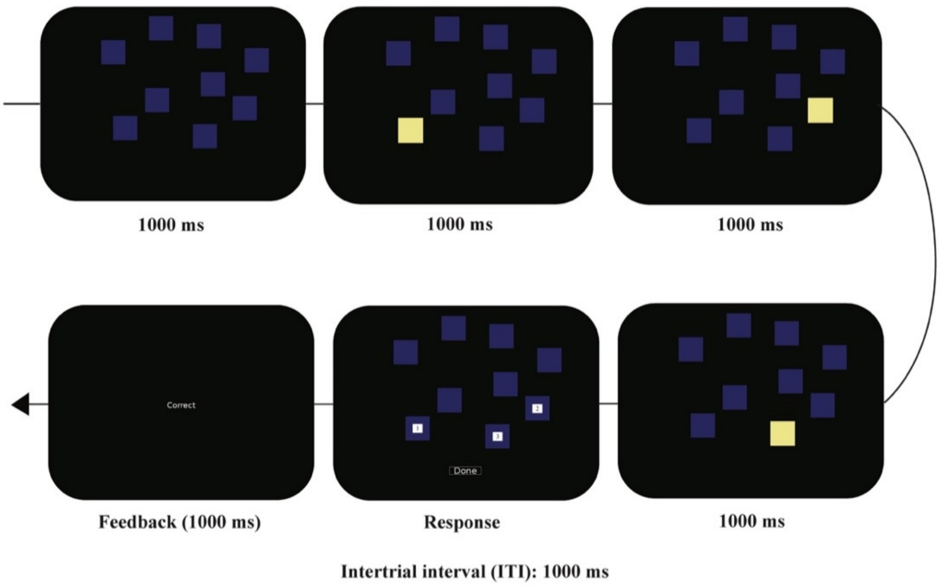
An example of the timeline of the trials presented during the forward digit span task. Images taken from the Psychology Experiment Building Language (PEBL), Version 2.1 (Mueller & Piper, 2014).



Corsi Block task. The Corsi Block task is a non-verbal test that was developed to assess an individual's visuospatial memory (Corsi, 1972). The task consists of 9 blocks irregularly positioned on the screen (see Figure 2.2). During the test phase, the blocks on the screen will light up in a specific sequence, and the observer is required to memorise the order in which the blocks lit up. During the test phase, the observer is required to replicate the sequence by clicking on the blocks in the correct order. The task will begin with a block sequence of two and will gradually increase up to a block sequence of nine. By increasing the length of the block sequence, the capacity of an individual's short-term memory can be assessed. At the end of the Corsi-Block task, an individual would obtain two scores, one indicating their block or memory span (ranging from 1 to 9) and the other indicates their total score (ranging from 0 to 144). Kessels and colleagues (2000) reported that the average block span for a typically developing individual is around 5 to 6 blocks.

Figure 2.2

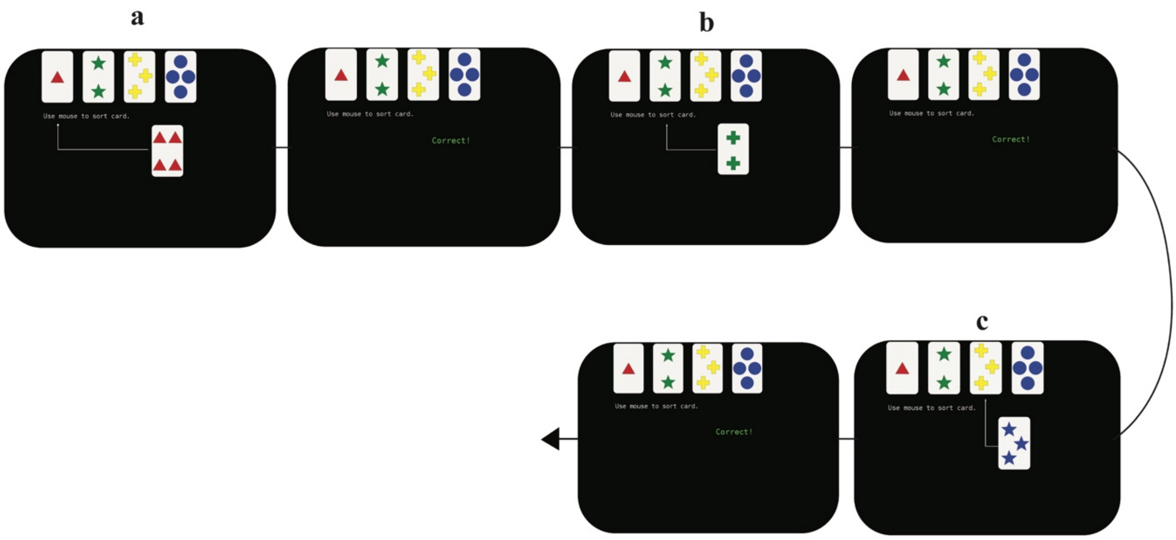
A computerized version of the Corsi Block task. Images taken from the Psychology Experiment Building Language (PEBL), Version 2.1 (Mueller & Piper, 2014).



Berg's Card Sorting task. The Berg's Card Sorting Task, better known as the Wisconsin's Card Sorting Task, assesses an individual's mental flexibility or ability to switch between different concepts or rules (Berg, 1948). During the test, participants are presented with four piles of cards at the top of the screen, each with various shapes, colours, and number of elements of them (see Figure 2.3). At the bottom of the screen, the participants will be presented with a deck of 128 cards. The deck is revealed one card at a time, and participants are required to sort the card in one of four piles depending on the rule of the test (e.g., same shape, colour, or number of elements). Upon successfully sorting 10 cards, the rule of the test changes. The new rule must be discovered by the participants via the trial-and-error method. This process will continue until all 128 cards are sorted, or if the participant completes all 9 sets (whichever comes first). When the task ends, participants will be provided with percentages of total errors, perseverative responses (when a card is matched according to the rule of the previous trial, regardless of whether the response is correct or not), perseverative errors (number of incorrect trials involving perseverative behaviour) and non-perseverative responses. Whereas some studies have utilised perseverative errors as a main measure of mental flexibility (Dann et al., 2023; Landry & Mitchell, 2021), the present study used perseverative responses as a main measure of mental flexibility. It is important to note, however, that the results of the present study did not differ much when perseverative errors were used as a measure of mental flexibility.

Figure 2.3

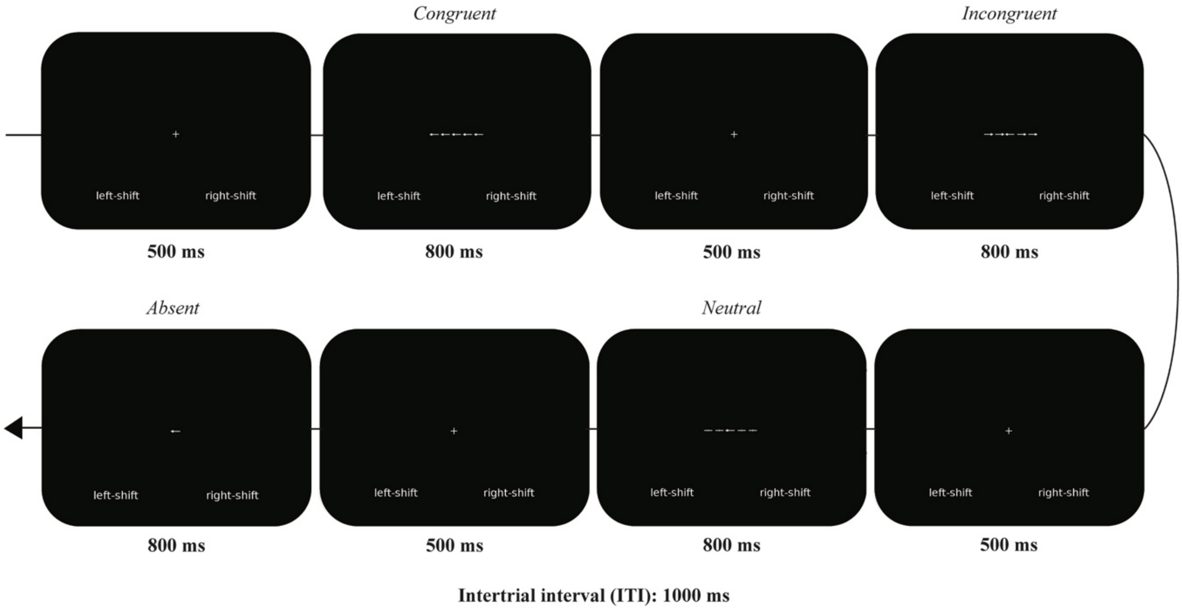
An example of the different trials presented during the Berg's Card Sorting test; ***a****: sort by shape,* ***b****: sort by colour,* ***c****: sort by number of elements. Images taken from the Psychology Experiment Building Language (PEBL), Version 2.1 (Mueller & Piper, 2014).*



Flanker task. The flanker task, on the other hand, measures the ability to inhibit non-relevant and prepotent responses to a non-verbal stimulus (Eriksen & Schultz, 1979). In a typical Flanker task, the central target – an arrow, is flanked by distractors (see Figure 2.4). These distractors will either point to the same direction as the central target (congruent condition), to the opposite direction of the central target (incongruent condition), to no direction (neutral condition), or be absent (absent condition). Studies have shown that people respond faster and at a higher accuracy in the congruent condition compared to the incongruent condition (Stins et al., 2008). At the end of the task, people are often given a mean of conflict cost which is the difference in the mean reaction times (RT) between congruent and incongruent trials (i.e., Conflict Cost = Incongruent RT – Congruent RT). For example, if the mean RT for the congruent trials is 438 ms and the mean RT for incongruent trials is 490 ms, then the conflict cost would be 52 ms.

Figure 2.4

A timeline of trials portraying the congruent (same direction), incongruent (opposite direction), neutral (no direction), and absent conditions in the Flanker task. Images taken *from the Psychology Experiment Building Language (PEBL), Version 2.1 (Mueller & Piper, 2014).*



Procedure

The present study was administered through the online survey platform Qualtrics (Qualtrics, Provo, UT). At the beginning of the experiment, participants were provided with an information sheet, a consent form, and were subsequently required to give some demographic information (e.g., gender, date of birth). Upon informed consent, participants began the experiment by watching a six-minute movie about a mock burglary (Takarangi et al., 2006). The video depicted a mock burglary committed by an electrician named 'Eric' who stole his client's personal belonging while working on several electrical jobs.

After the movie ended, participants completed an Autobiographical Memory Test (AMT; Williams & Broadbent, 1986). They were given five emotional and five neutral cue words and were subsequently required to describe a personal experience that corresponded to each cue. Once they successfully retrieved and described a past personal event, they were asked to rate the recollective experience for each memory (e.g., "When you think about the event, do you feel as though you are reliving it?") on a 7-point Likert scale. After retrieving all 10 memories, they proceeded to complete a 20-item recognition test about the mock burglary. Participants were given a score out of twenty as a measure of their memory accuracy. Next, they were given two questionnaires to complete: the TALE and RRS. A figure of the tasks administered on Qualtrics can be found in Figure A1 in Appendix A.

Once both questionnaires were complete, participants were given a five-minute break. After the break, the participants completed five computerized executive functioning tasks on an open-source software known as the Psychology Experiment Building Language (PEBL), Version 2.1 (Mueller & Piper, 2014). The first task they completed was the Berg's Card Sorting Task. Before the task began, participants were informed that they would be presented with four piles of cards (each with a different number of elements, colours, and shapes) that will be displayed at the top of the screen, and an individual card will be displayed at the bottom of the screen. They were then instructed to sort the individual card into one of the four piles based on a certain rule (unknown to the participants), by clicking on the pile they think the individual card belongs to. They were also told that they would be provided with feedback of either 'correct' or 'wrong' to indicate whether they had sorted each individual card correctly. After successfully sorting 10 cards, the rule of the task changed, and participants had to figure out the new rule by using the trial-and-error method via the feedback provided. The task ended as soon as the participants sorted all 128 cards correctly or when they successfully completed all 9 rule changes (whichever comes first).

Next, participants completed the second executive functioning task known as the Corsi Block task. At the beginning of the task, participants were told that they would be presented with nine blocks that would light up in a specific sequence. They were then asked to memorize the sequence in which the blocks lit up in, and were subsequently instructed to click the blocks in the same order that they lit-up in. Participants began the task with three practice trials. Once the practice trials ended, the task began with a block length of two and gradually increased to a block length of nine. There were two trials in each block sequence, and if the participants successfully completed either one, or both trials of the same sequence successfully, they were able to proceed to the next trial with an increased block length. However, if they failed to reproduce the order of the blocks in both trials of the same sequence correctly, the test ended.

Upon completing the Corsi Block task, participants were presented with the Flanker task. Before the task began, participants were asked to pay attention to the direction that the central arrow was pointing to. They were explicitly instructed to ignore the flankers surrounding the central arrow. Furthermore, they were also informed that the flankers will either point to the same direction (congruent condition), the opposite direction (incongruent condition), be absent (absent condition), or will only appear as lines (neutral condition). During the task, the participants were presented with a fixation cross at the centre of the screen for 500 milliseconds, and this was immediately followed by the presentation of an array of equally spaced white arrows for 800 milliseconds. If the arrow was pointing to the right region, participants pressed the right ‘shift’ key, and if the arrow was pointing to the left region, they pressed the left ‘shift’ key. Participants were told to make a response as quickly and as accurately as possible. There was a total of 160 trials (40 neutral, 40 congruent, 40 incongruent, and 40 absent) in the task.

The fourth executive functioning task that participants completed was the Forward Digit Span task. At the beginning of the task, they were instructed to memorize a sequence of digits that were presented to them and were told that they would need to input the string of digits in the exact order that they were presented in (e.g., the string ‘1-5-9-3-7’ would be entered as ‘1-5-9-3-7’). Participants were asked to press the ‘Enter’ key when they were done. They were told that they will be provided with feedback of ‘correct’ or ‘wrong’ to indicate whether they had remembered the order of the digits correctly. If they were unable to remember the order of the digits halfway through their response, they were told to press the '-' key. The test began with a sequence length of 3 digits and progressively increased to a sequence length of 10 digits. Participants completed two trials for each digit length. The test ended when the participants completed the last trial of the ten-digit sequence.

Upon completing the Forward Digit Span task, participants completed the Backward Digit Span task. The Backward Digit Span task possessed similar instructions to the Forward Digit Span task. However, the only difference was that they were required to input the digits in a reversed order, and not in the order in which they were presented in (e.g., the string '12345' would be inputted as '54321').

After completing the backward digit span task, the experiment ended, and the participants were thanked for their participation. Each session took approximately 120 minutes to complete. Participants received a monetary compensation of RM80 (RM40/twin) for their participation.

Coding

The specificity of the descriptions provided were coded by two independent researchers using a four-point coding system (Debeer et al., 2009) and the agreement between the researchers was moderately high, $k = .82$. Any disagreements between the researchers were resolved through discussion. A memory was coded as specific and was given a score of 4 if the event occurred at a particular time or place and lasted no longer than a day. An example of a specific memory would be "I got angry at my parents last week because they didn't allow me to go and hang out with my friends at the park". If participants provided descriptions for events lasting longer than a day (e.g., "When my family and I went to Melaka for 3 days"), their memory would be considered as an extended event and will be given a score of 3. Categoric memories, on the other hand, are memories for repeated events (e.g., “I was an active student in university, so I took up a lot of tasks and participated in many activities”) and were given a score of 2. Semantic associations which are direct verbal associations of the cue word (e.g., “I live in Kuala Lumpur) were given a score of 1. Finally, if participants had difficulties retrieving an autobiographical memory, their response would be considered as an omission and these descriptions were given a 0.

The memories were then further categorised into specific memories and non-specific memories. Whereas specific memories were given a score of 1, non-specific memories and omissions were given a score of 0. The specificity score for each participant was then calculated by summing the number of specific memories retrieved across the 10 cue words.

Results

Descriptive Statistics

To examine the relationships between different memory characteristics, we first calculated the mean scores and standard deviations for each aspect: memory accuracy, memory specificity, recollective experience, the three subscales of rumination, the three subscales of memory functionality, and the five executive-functioning processes (i.e., mental flexibility, visuospatial learning, inhibition, and forward and backward verbal learning). The means and standard deviations for each aspect are included in Table 2.4.

Correlations Within Memory Characteristics and Processes

Sixteen bivariate analyses were conducted to examine the intercorrelations between the three subscales of the RRS, the three subscales of the TALE, and the five different processes of executive functioning. Our findings revealed several moderate correlations between the three subscales of the RRS. First, we found a moderate correlation between the brooding and the depression subscale, $r(182) = .678$, $p < .001$, 95% CI [.591, .749], $R^2 = .460$. Second, we found strong correlations between the brooding and reflection subscale, $r(182) = .337$, $p < .001$, 95% CI [.202, .459], $R^2 = .113$, and between the depression and reflection subscale of the RRS, $r(182) = .498$, $p < .001$, 95% CI [.380, .599], $R^2 = .248$.

Besides the three subscales of the RRS, there were several weak to moderate associations that were found between the three subscales of the TALE. Weak positive correlations were found between the social and directing-behaviour subscale, $r(182) = .348$, $p < .001$, 95% CI [.214, .469], $R^2 = .121$, and between the social and self-continuity subscale, $r(182) = .308$, $p < .001$, 95% CI [.171, .434], $R^2 = .094$. A moderate association was also found between the directing-behaviour and the self-continuity subscale of the TALE, $r(182) = .484$, $p < .001$, 95% CI [.365, .588], $R^2 = .234$. All these results remained significant after a Bonferroni correction was applied (i.e., .05/91 = .0005)

When examining the associations between the five executive functioning processes (i.e., mental flexibility, visuospatial learning, inhibition, and forward and backward verbal learning), we only found two associations that were significantly different from zero. Our analyses showed a weak association between both the forward and backward process of verbal learning, $r(182) = .468$, $p < .001$, 95% CI [.347, .574], $R^2 = .219$. A weak correlation was also found between the forward verbal learning and visuospatial learning process, $r(182) = .265$, $p < .001$, 95% CI [.126, .395], $R^2 = .070$.

Correlations Between Memory Characteristics and Processes

Besides the intercorrelations between the three subscales of the RRS, the three subscales of the TALE, and the five different executive functions, we found a few significant correlations across the different aspects of autobiographical memory. Interestingly, there were several weak correlations between the subscales of the RRS and TALE.

There was a weak correlation between the brooding items and the social function, $r(182) = .276, p < .001$, 95% CI [.137, .405], $R^2 = .076$, between the brooding items and the directing-behaviour function, $r(182) = .221, p = .003$, 95% CI [.079, .354], $R^2 = .048$, and between the brooding items and the self-continuity function, $r(182) = .265, p < .001$, 95% CI [.126, .395], $R^2 = .070$. Our analyses also revealed a weak positive correlation between the depression items and the social bonding function, $r(182) = .275, p < .001$, 95% CI [.136, .404], $R^2 = .075$, between the depression items and the directing-behaviour function, $r(182) = .175, p = .018$, 95% CI [.031, .311], $R^2 = .031$, and between the depression items and the self-continuity function, $r(182) = .344, p < .001$, 95% CI [.209, .465], $R^2 = .118$. Moreover, a weak correlation was found between the reflection items and the directing behaviour function, $r(182) = .183, p = .013$, 95% CI [.040, .319], $R^2 = .033$, and between the reflection items and the self-continuity function, $r(182) = .302, p < .001$, 95% CI [.164, .428], $R^2 = .091$. The associations between the directing behaviour function and the brooding, reflection, and depression items of the RRS did not remain significant once a Bonferroni correction had been applied.

For the recollective experience measure, only the items on the TALE and RRS had significant associations. For instance, a positive association was found between recollective experience and the brooding items, $r(182) = .154, p = .037$, 95% CI [.009, .292], $R^2 = .024$, and between recollective experience and the depression items of the RRS, $r(182) = .211, p = .004$, 95% CI [.068, .345], $R^2 = .044$. Where memory functionality is concerned, a positive correlation was found between recollective experience and the social bonding function, $r(182) = .216, p = .003$, 95% CI [.074, .350], $R^2 = .047$, between recollective experience and the directing behaviour function, $r(182) = .168, p = .022$, 95% CI [.024, .306], $R^2 = .028$, and between recollective experience and the self-continuity function, $r(182) = .196, p = .008$, 95% CI [.053, .331], R^2 = .038. When a Bonferroni correction was applied, none of these associations remained significant.

When we further examined the associations between the different aspects, we found a weak negative correlation between memory specificity and the mental flexibility process of executive functioning, $r(182) = -.173$, $p = .019$, 95% CI [−.310, −.029], R^2 = .030. There were also several correlations between the executive functioning tasks and the items on the TALE and the RRS. Visuospatial learning was related to the reflection items of the RRS, $r(182) = -.181$, $p = .014$, 95% CI [−.317, −.037], R^2 = .033, and the self-continuity function of the TALE, $r(182) = -.149$, $p = .043$, 95% CI [−.288, −.005], R^2 = .022. However, none of these associations remained significant when a Bonferroni correction was applied.

Bayesian Analyses

The correlations reported in the previous section did not reveal significant associations between memory specificity, memory accuracy, recollective experience, and the five executive functioning processes. However, a limitation with null hypothesis significance testing is that the lack of significant results does not indicate the absence of a relationship. To determine whether aspects, such as memory accuracy, memory specificity, recollective experience, and executive processes, were truly independent of other aspects, we performed a series of Bayesian correlational analyses for these associations.

The outcome of these Bayesian analyses is represented by the Bayesian Factor (BF_{01}), whereby values of 3 and higher reflect moderate evidence for the null hypothesis, values of 10 and higher strong evidence, values of 30 and higher very strong evidence, and values of 100 and higher extreme evidence. Values between 1 and 3 are considered anecdotal evidence (Lee & Wagenmakers, 2014).

The Bayes factors for the relationship between memory accuracy and the other aspects – memory specificity (BF_{01} = 2.68), recollective experience (BF_{01} = 6.81), the three subscale of memory functionality (BF_{01} = 3.30 – 10.83), the three subscales of rumination (BF_{01} = 4.17 – 10.11), and the mental flexibility (BF_{01} = 7.63), inhibition (BF_{01} = 10.33), visuospatial learning (BF_{01} = 8.59), and the forward (BF_{01} = 10.48) and backward verbal learning (BF_{01} = 6.39) processes of executive functioning – suggest anecdotal to strong (but mostly moderate) evidence for the null hypothesis.

A similar pattern was also observed for the relationship between memory specificity and the other aspects: recollective experience (BF_{01} = 8.19), the three subscales of rumination (BF_{01} = 2.33 – 10.77), the three subscales of memory functionality (BF_{01} = 3.96 – 10.75), and the mental flexibility (BF_{01} = 0.71), inhibition (BF_{01} = 10.81), visuospatial learning (BF_{01} = 10.69), and the forward (BF_{01} = 10.73) and backward verbal learning (BF_{01} = 7.93) processes of executive functioning. Except for mental flexibility, there was mostly moderate to strong evidence in favour of the null hypothesis.

Our data also provides anecdotal to strong evidence for the lack of associations between recollective experience and executive functioning processes, such as mental flexibility (BF_{01} = 9.28), inhibition (BF_{01} = 2.76), visuospatial learning (BF_{01} = 10.35), and the forward (BF_{01} = 10.45) and backward verbal learning (BF_{01} = 8.64).

Finally, we also found anecdotal to strong evidence for the null hypothesis for the relationship between the five executive functioning processes and the brooding (BF_{01} = 7.25 – 10.77), depression (BF_{01} = 5.79 – 10.72), and reflection (BF_{01} = 0.55 – 9.98) subscales of the RRS, and between the five executive functioning processes and the directing behaviour (BF_{01} = 5.84 – 10.83), social bonding (BF_{01} = 1.79 – 10.66), and self-continuity (BF_{01} = 1.42 – 9.22) functions of the TALE. The Bayesian Factors for the correlations between different aspects of memory can be found in Table A1 in Appendix B.

Secondary Analysis: Memory Specificity

Because a disproportionate number of omissions could influence the means of memory specificity and recollective experience, a one-way ANOVA was conducted to determine whether the mean number of specific memories, non-specific memories (i.e., extended memories, categorical memories, and semantic associations), and omissions differed, $F(2, 549) = 565.25$, $p < .001$, $\eta_p^2 = .673$. Overall, we found that participants retrieved more specific memories ($M = 6.32$, $SD = 2.22$) than non-specific memories ($M = 3.59$, $SD = 2.13$) or omissions ($M = 0.08$, $SD = 0.30$), *p*s < .001. They also retrieved more non-specific memories than omissions, $p < .001$. These findings suggest that omissions were rare. On average, out of ten participants, only one participant had difficulties retrieving a memory for one cue word.

Table 2.4

The means, standard deviations, and Pearson's correlation values for the different aspects of autobiographical memory.

		Executive Functioning Tasks							RRS			TALE		
	Mean scores (SD)	Recollective experience	Memory accuracy	Inhibition	Mental Flexibility	Visuospatial Learning	Verbal learning – Forward	Verbal Learning – Backward	Brooding	Depression-related	Reflection	Social	Directing-behaviour	Self-continuity
Memory specificity	6.32 (2.22)	-.056	.124	.005	-.173	.012	.011	.059	-.008	.099	.130	.009	-.064	.106
Recollective experience	5.10 (0.87)	--	.072	.123	.041	-.023	-.020	-.050	.154	.211	.133	.216	.168	.196
Memory accuracy	15.68 (2.04)		--	.023	-.062	-.051	.019	.077	-.103	-.028	-.032	.015	.115	.003
Inhibition	43.32 (22.45)			--	-.110	-.027	.079	.074	.049	-.021	.030	.083	-.035	-.056
Mental Flexibility	0.32 (0.067)				--	-.121	-.089	-.086	.067	.066	.042	.014	-.083	.042
Visuospatial Learning	62.65 (24.95)					--	.265**	.136	-.008	-.011	-.181	.086	-.047	-.149
Verbal learning – Forward	7.65 (1.50)						--	.468**	-.067	-.036	.036	.075	.056	-.132

Verbal Learning – Backward	7.49 (1.77)	--	-.046	-.083	-.037	.141	-.004	-.141
Brooding	2.55 (0.69)		--	.678**	.337**	.276	.221	.265
Depression-Related	2.44 (0.58)			--	.498**	.275**	.175	.344**
Reflection	2.24 (0.67)				--	.132	.183	.302**
Social	3.41 (0.83)					--	.348**	.308**
Directing-behaviour	3.63 (0.72)						--	.484**
Self-continuity	3.05 (0.90)							--

Note. Standard deviations are reported in parentheses. RRS = Ruminative Response Scale; TALE = Thinking About Life Experiences Scale; Levels of significance are denoted after Bonferroni correction (** p < .001).

Discussion

In the present study, we aimed to better understand the fundamental processes underlying memory retrieval by examining the associations between six aspects of autobiographical memory: memory accuracy, memory specificity, recollective experience, the three subscales of rumination, the three subscales of memory functionality, and five executive functioning processes (i.e., mental flexibility, visuospatial learning, inhibition, and forward and backward verbal learning). Because impaired executive functioning and rumination are both known to contribute to reduced autobiographical memory specificity (Williams, 2006; Williams et al., 2007), we expected to find an association between memory specificity, the three subscales of the RRS, and the five processes of executive functioning. However, contrary to our expectations, rumination and executive functioning did not correlate with memory specificity.

Despite the lack of correlations between the three components, we found several intercorrelations between the three subscales of the TALE, the three subscales of the RRS, and the five executive functioning processes. For instance, the brooding, depression, and reflection items of the RRS were moderately correlated with each other and this finding is in line with prior works (Nolen-Hoeksema & Morrow, 1991). There were also moderate correlations between the directive, social-bonding, and self-continuity functions of the TALE, indicating that the three subscales measured three different but related aspects of memory functionality (Alea et al., 2015; Caci et al., 2020). Furthermore, the correlations between the subscales of the RRS and the subscales of the TALE found in the present study further confirms the findings of previous studies suggesting that both the TALE and RRS questionnaires are reliable across different cultural contexts (Alea & Ali, 2018; Extremera & Fernández-Berrocal, 2006; Park et al., 2021).

When examining the correlations between the five different executive functioning processes, we only found two significant associations. There was a weak correlation between the forward and backward verbal learning processes of executive functioning, suggesting that both processes employ the phonological storage of short-term memory (Alloway et al., 2006). There was also a correlation between visuospatial learning and the forward verbal learning process of executive functioning. The involvement of visuospatial processing during forward verbal learning is supported by neuroimaging studies (Hoshi et al., 2000; Manan et al., 2014). For instance, Hoshi et al. (2000) reported activations in the dorsolateral prefrontal cortex (an area commonly associated with visuospatial processing) for the forward verbal learning processes of executive functioning. Therefore, it is possible that participants in the present study used their visuospatial skills to complete the forward digit span task.

In terms of the correlations between the different aspects of memory, we found that the brooding, depression, and reflection subscales of the RRS were correlated with the social bonding and self-continuity subscales of the TALE, suggesting a relationship between memory functionality and rumination. The correlations between the remaining aspects of autobiographical memory, such as memory accuracy, memory specificity, recollective experience, and executive functioning, were not significantly different from 0, suggesting that these aspects of memory function more independently.

We believe that the independence of these aspects may be related to our methodology. However, the lack of correlations observed could also stem from other factors that may have affected the reliability of our results, such as the characteristics of the sample, online data collection, and challenges related to the pandemic. For example, it is possible that we did not observe significant associations between some aspects of memory because our sample consisted of twins who were generally unfamiliar with psychological research. Without a background in research, they may have been more susceptible to demand characteristics, potentially responding to questionnaires and tasks in a way they assumed were expected in behavioural research (Fabrigar et al., 2020; Corneille & Lush, 2023). Furthermore, data collection for the present study was conducted online due to the COVID-19 pandemic. Although rigorous steps (e.g., using software, such as Qualtrics and PEBL, that are optimised for online data collection) were taken to ensure the reliability of the data, there may have been unique stressors and challenges that participants faced during the pandemic, which could have introduced some noise in the data. For example, Al-Habaibeh et al. (2021) conducted a survey among adults working remotely in the UK during the COVID-19 lockdown. The authors reported that factors, such as the lack of face-to-face communication, reduced support from colleagues, lack of resources required, and family distractions, were just a few of the challenges people faced while working remotely during the lockdown. Similar results have also been reported for studies involving students and frontline workers during the pandemic (Malik et al., 2022; Mayers et al., 2022). Due to the challenges related to the pandemic, participants in our study may have lacked the motivation to complete an online experiment lasting two hours or more, potentially affecting the depth and authenticity of their responses.

Given the factors that may have affected the reliability of the results of the present study, we planned to conduct a follow-up study with some minor adjustments: (1) We recruited university students who are more accustomed to psychological research. (2) We also conducted our study in-person in a laboratory setting which allows us to control and optimise conditions for psychological research. (3) The follow-up study was conducted about a year after the pandemic with the hopes that the challenges related to the pandemic would be mitigated.

Study 2

In the first study of this chapter, we examined the relationships between the different aspects of autobiographical memory, including memory accuracy, memory specificity, recollective experience, rumination, memory functionality, and executive functioning. Whereas memory functionality and rumination were related, the other aspects of autobiographical memory appeared to function more independently. Although the first study was sufficiently powered ($N = 184$), factors, such as sample characteristics, online data collection, and challenges related to the pandemic, may have reduced the reliability of the data. To address these limitations, the present study was conducted in-person in a laboratory, with university students approximately one year after the Malaysian Movement Control Order (MCO).

Method

Participants

An a priori power analysis using G*Power (Faul et al., 2007) was conducted to determine the number of participants required for a correlational study with six variables. The analysis indicated that a sample size of 149 participants would be adequate for the present study. The effect size was medium ($f = .25$), the alpha level was .003 (i.e., .05/15 = 0.003), and the power was 0.80. Unlike data collection in Study 1 which was conducted online, data collection for the present study was conducted in-person.

We recruited 161 participants via the convenience sampling method from the University of Nottingham Malaysia. Because one of our participants was diagnosed with major depressive disorder (MDD), their data was excluded from the analyses. Additionally, we removed the datasets of two participants because the program running the executive functioning tasks crashed during the completion of the experiment. Three participants were also removed because they achieved less than 50% accuracy (a score of 10 out of 20) on the recognition task. Finally, we removed the datasets of two participants because they performed poorly in the Corsi Block task (obtained a score of 1 out of 9) and the digit span task (obtained a score of 2 out of 10), respectively. The final sample, therefore, comprised 153 participants (28 males and 125 females) who were between 18 and 27 years old (M = 20.93 years, SD = 1.86). The present study was approved by the Science and Engineering Research Ethics Committee (SEREC) of the University of Nottingham Malaysia (AFCM210319).

Materials and Procedure

Following the procedure of Study 1, participants began the experiment by watching a video on YouTube depicting a mock burglary (Takarangi et al., 2006). After viewing the video, they completed an AMT (Williams & Broadbent, 1986) where they recalled a specific memory in response to ten single-word cues (i.e., sad, river, angry, fire, love, book, happy, city, fear, and flower) and rated each memory on their recollective experience. Once participants completed the AMT, they proceeded with a recognition task which measured accuracy for items in the video they had watched. Following the recognition task, participants completed the RRS and the TALE, which measured rumination and memory functionality, respectively.

After a five-minute break, participants completed five executive functioning tasks. These include the Berg's Card Sorting task (Berg, 1948) which measures mental flexibility, the Corsi Block task (Corsi, 1972) which measures visuospatial learning, the Flanker task which measures inhibition (Eriksen & Schultz, 1979), the Forward Digit Span task which measures forward verbal learning, and the Backward Digit Span task which measures backward verbal learning (Wechsler, 2008). Each session lasted approximately 120 minutes, and at the end of the sessions, participants were rewarded with either RM 20 or 2.0 SONA credits for their participation.

Coding

To establish specificity, the autobiographical memories in the present study were coded by two independent researchers using a four-point scoring system: Memories for specific events (occurring within a day) were given a score of 4; extended memories (for events that occurred over an extended period of time) were given a score of 3; categoric memories (memories for repeated events) received a score of 2, semantic associations (a direct association of the cue) were given a score of 1; and omissions were scored as 0. The inter-rater agreement was high, $k = .86$.

Subsequently, the individual memories were categorised into specific and non-specific memories. Whereas specific memories were given a score of 1, non-specific memories and omissions were given a score of 0. The specificity score for each participant was then calculated by summing the number of specific memories retrieved across the 10 cue words.

Results

Descriptive Statistics

To better understand the relationships between the different aspects of autobiographical memory, we calculated the means and standard deviations for the aspects. The means and standard deviations for the aforementioned aspects are provided in Table 2.5.

Correlation Within Memory Characteristics and Processes

In accordance with Study 1, we first examined the intercorrelations between the three subscales of the RRS, the three subscales of the TALE, and the five executive functioning processes. Within the subscales of the RRS, we observed positive associations between the brooding and depression items, $r(151) = .666$, $p < .001$, 95% CI [.568, .746], $R^2 = .443$, as well as between the brooding and reflection items, $r(151) = .417$, $p < .001$, 95% CI [.276, .540], $R^2 = .173$. Additionally, a weak correlation was also found between the depression and reflection items of the RRS, $r(151) = .417$, $p < .001$, 95% CI [.276, .540], $R^2 = .173$.

A similar pattern also emerged among the subscales of the TALE. We observed moderate associations between the social bonding and directing behaviour functions, $r(151) = .401$, $p < .001$, 95% CI [.259, .526], $R^2 = .160$, and between the social bonding and self-continuity functions, $r(151) = .232$, $p = .004$, 95% CI [.076, .376], $R^2 = .053$. The directing behaviour function was also moderately correlated with the self-continuity function, $r(151) = .448$, $p < .001$, 95% CI [.312, .567], $R^2 = .201$. However, after applying a Bonferroni correction (i.e., .05/91 = .0005), the correlation between the social bonding and self-continuity functions of the TALE was no longer significant.

When examining the associations between the five executive functioning processes, there were four significant associations. Forward verbal learning was correlated with backward verbal learning, $r(151) = .538$, $p < .001$, 95% CI [.415, .642], $R^2 = .289$, visuospatial processing, $r(151) = .244$, $p = .002$, 95% CI [.088, .387], $R^2 = .060$, and inhibition processes, $r(151) = .168$, $p = .038$, 95% CI [.009, .318], $R^2 = .028$. There was also a correlation between backward verbal learning and visuospatial processing, $r(151) = .204$, $p = .011$, 95% CI [.047, .351], $R^2 = .042$. When a Bonferroni correction was applied, only the correlation between forward verbal learning and backward verbal learning remained significant.

Correlations Between Memory Characteristics and Processes

When examining the correlations across the different aspects of memory, our correlations were consistent with those of Study 1. A moderate association was observed between the memory functionality and rumination aspects of autobiographical memory. There were positive associations between the brooding items and the social bonding function, $r(151) = .237$, $p = .003$, 95% CI [.082, .382], $R^2 = .056$, between the brooding items and the directing behaviour function, $r(151) = .169$, $p = .037$, 95% CI [.011, .319], $R^2 = .028$, and between the brooding items and the self-continuity function, $r(151) = .400$, $p < .001$, 95% CI [.258, .526], $R^2 = .160$. Whereas the depression items correlated with the social bonding function, $r(151) = .212$, $p = .009$, 95% CI [.055, .358], $R^2 = .045$, and the self-continuity function, $r(151) = .349$, $p < .001$, 95% CI [.201, .481], $R^2 = .122$, the reflection items correlated with the social bonding function, $r(151) = .251$, $p = .002$, 95% CI [.096, .394], $R^2 = .063$, the directing behaviour function, $r(151) = .338$, $p < .001$, 95% CI [.189, .471], $R^2 = .114$, and the self-continuity function, $r(151) = .429$, $p < .001$, 95% CI [.291, .551], $R^2 = .184$. The associations between the brooding items of the RRS and the directing behaviour function of the TALE, as well as the associations between the social bonding function of the TALE and the brooding items, depression items, and reflection items of the RRS, did not remain significant once a Bonferroni correction was applied.

Furthermore, the measure of recollective experience was weakly correlated with memory functionality. We observed positive correlations between recollective experience and the directing behaviour function of the TALE, $r(151) = .284$, $p < .001$, 95% CI [.131, .424], $R^2 = .081$, as well as between recollective experience and the self-continuity function, $r(151) = .165$, $p = .041$, 95% CI [.007, .315], $R^2 = .027$.

Other aspects of autobiographical memory, such as memory accuracy and the inhibition process of executive functioning, also correlated with the RRS and TALE subscales, respectively. For instance, a weak correlation emerged between memory accuracy and the social bonding function of the TALE, $r(151) = .177$, $p = .029$, 95% CI [.019, .326], $R^2 = .031$. In addition, a weak correlation was observed between the inhibition process of executive functioning and the depression items of the RRS, $r(151) = -.166$, $p = .040$, 95% CI [−.317, −.008], $R^2 = .028$. After applying a Bonferroni correction, only the correlation between recollective experience and the directing behaviour function of the TALE remained significant.

Bayesian Analyses

The correlations reported in the previous section did not reveal significant associations between memory accuracy, memory specificity, recollective experience, and the five executive functioning processes. To determine whether these aspects were truly independent of each other, we conducted a series of Bayesian analyses for these associations.

With the exception of the association between memory accuracy and the social bonding function of the TALE ($BF_{01} = 0.93$), we found anecdotal to moderate evidence for the null hypothesis for the associations between memory accuracy and the other aspects of memory: memory specificity ($BF_{01} = 8.88$), recollective experience ($BF_{01} = 4.71$), the two subscales of memory functionality ($BF_{01} = 9.85 – 9.86$), the three subscales of rumination ($BF_{01} = 9.36 – 9.86$), and the mental flexibility ($BF_{01} = 6.57$), inhibition ($BF_{01} = 9.88$), visuospatial learning ($BF_{01} = 6.77$), and the forward ($BF_{01} = 2.26$) and backward ($BF_{01} = 3.40$) verbal learning processes of executive functioning.

We also found anecdotal to moderate evidence for the relationship between memory specificity and other aspects: recollective experience ($BF_{01} = 9.21$), the three subscales of memory rumination (BF_{01} = 4.86 – 8.98), the three subscales of memory functionality (BF_{01} = 4.86 – 8.72), and the mental flexibility (BF_{01} = 1.76), inhibition (BF_{01} = 8.93), visuospatial processing (BF_{01} = 9.74), and the forward (BF_{01} = 6.63) and backward (BF_{01} = 7.52) verbal learning processes of executive functioning.

Finally, findings from this study also revealed anecdotal to moderate evidence for the relationship between the five executive functioning processes and recollective experience (BF_{01} = 6.26 – 9.56), between the five executive functioning processes and the brooding (BF_{01} = 2.35 – 6.92), depression (BF_{01} = 1.23 – 8.31), and reflection (BF_{01} = 3.35 – 8.62) subscales of the RRS, and between the five executive functioning processes and the directing behaviour (BF_{01} = 6.15 – 9.84), social bonding (BF_{01} = 1.77 – 9.02), and self-continuity (BF_{01} = 6.95 – 9.86) functions of the TALE. The Bayesian Factors for the correlations between different aspects of memory can be found in Table A2 in Appendix C.

Secondary Analysis: Memory Specificity

Because a high number of omissions could influence the estimates of the means of memory specificity and recollective experience, we conducted a one-way ANOVA to determine whether the mean number of specific memories, non-specific memories and omissions differed, $F(2, 456) = 812.62$, $p < .001$, $\eta_p^2 = .781$. Like Study 1, we found that participants retrieved more specific memories ($M = 7.34$, $SD = 1.99$) than non-specific memories ($M = 2.61$, $SD = 1.93$) or omissions ($M = 0.04$, $SD = 0.24$), *p*s < .001. They also retrieved more non-specific memories than omissions, $p < .001$. Similar to the findings of Study 1, the present study showed that on average, out of ten participants, only one participant had difficulties retrieving a memory for one cue word.

Table 2.5

The means, standard deviations, and Pearson's correlation values for the different aspects of autobiographical memory.

				Executive Functioning Tasks					RRS			TALE		
	Mean scores (SD)	Recollective experience	Memory accuracy	Inhibition	Mental Flexibility	Visuospatial Learning	Verbal learning – Forward	Verbal Learning – Backward	Brooding	Depression-related	Reflection	Social	Directing-behaviour	Self-continuity
Memory specificity	7.34 (1.99)	-.031	.038	-.037	-.151	.014	-.073	-.061	-.097	.036	.061	.097	-.050	.041
Recollective experience	4.88 (0.97)	--	.100	-.021	-.078	.031	.052	-.073	.110	.083	.087	.124	.284**	.165
Memory accuracy	15.47 (2.14)		--	.002	-.074	.071	-.140	-.119	-.006	-.019	-.027	.177	.007	.005
Inhibition	49.22 (21.00)			--	.020	-.021	.168	.067	-.086	-.166	-.071	.037	.080	-.058
Mental Flexibility	0.33 (0.058)				--	-.120	-.146	-.088	-.138	-.071	-.120	-.149	-.059	-.069
Visuospatial Learning	66.03 (26.58)					--	.244	.204	-.069	.048	.062	.035	.078	.023
Verbal learning – Forward	7.69 (1.44)						--	.538**	-.069	-.067	-.043	-.151	.008	-.042

Verbal Learning – Backward	7.16 (1.76)	--	-.083	-.062	-.072	-.083	.022	.006
Brooding	2.70 (0.73)		--	.666**	.417**	.237	.169	.400**
Depression-Related	2.65 (0.60)			--	.417**	.212	.149	.349**
Reflection	2.53 (0.62)				--	.251	.338**	.429**
Social	3.67 (0.81)					--	.401**	.232
Directing-behaviour	3.73 (0.69)						--	.448**
Self-continuity	3.26 (0.91)							--

Note. Standard deviations are reported in parentheses. RRS = Ruminative Response Scale; TALE = Thinking About Life Experiences Scale; Levels of significance are denoted after Bonferroni correction (** $p < .001$).

Discussion

Consistent with the findings of Study 1, we found moderate intercorrelations between the brooding, depression, and reflection subscales of the RRS (Nolen-Hoeksema & Morrow, 1991). Whereas the previous study showed positive associations between the three subscales of the TALE, only the associations between the directing behaviour and social bonding functions and between the directing behaviour and self-continuity functions of the TALE remained significant in the present study. In terms of the correlations between the five executive-functioning tasks, we only found an association between forward and backward verbal learning. The correlations between visuospatial learning and forward verbal learning and between the social bonding and self-continuity functions of the TALE observed in Study 1 were no longer significant. The intercorrelations between the three subscales of the RRS, the three subscales of the TALE, and the five executive functioning processes are discussed in detail in the General Discussion section.

When we examined the correlations between the different aspects of autobiographical memory, some of the correlations that were not significant in Study 1 were significant in the present study. For instance, we found a relationship between recollective experience and the directing behaviour function of the TALE, suggesting a relationship between recollective experience and memory functionality (see General Discussion for more details). Similar to the first study of this chapter, we also observed a positive relationship between the memory functionality and rumination. There were three significant associations between the brooding, depression and reflection subscales of the RRS and the self-continuity function. Unlike Study 1, however, the present study found a significant association between the reflection subscale and the directing behaviour function of the TALE too. Our finding suggests that apart from using their memories to understand their past behaviours, participants in our study also used the lessons learnt from their past to guide their present and future actions. The correlations between the brooding subscale and the social bonding function as well as between the depression subscale and the social bonding function did not remain significant in the present study.

Apart from a relationship between memory functionality and rumination and between memory functionality and recollective experience, there were no significant associations between the remaining aspects of memory (e.g., memory specificity, memory accuracy, and executive functioning). Our findings suggest that these aspects of memory may operate more independently. This interpretation was supported by the outcomes of the Bayesian analyses, which often showed moderate to strong support for the null hypothesis that these aspects are unrelated. Alternatively, the lack of correlations between the different aspects of memory could also be due to the unreliability of the measures administered across both studies. Whereas aspects such as recollective experience, memory functionality, and rumination were measured using self-report tasks, the five processes of executive functioning were measured using behavioural tasks. Given self-report measures and behavioural tasks often tap into different constructs (Dang et al., 2020), they may not have been sensitive enough to detect potential relationships between the various aspects of memory (see Chapter 5 for more details).

In Study 1, we were mainly concerned about the reliability of our data due to several factors, such as recruiting twins who were mostly unfamiliar with experimental research, noise brought about by online data collection, and the impact of the pandemic on people's overall wellbeing. Despite some new associations, such as those between recollective experience and the directing behaviour function, and between the reflection subscale and the directing behaviour function, as well as the lack of correlations between visuospatial learning and forward verbal learning, between the social bonding and self-continuity functions, between brooding subscale and the social bonding function, and between the depression subscale and the social bonding function, our results remained mostly consistent with the first study of this chapter. The consistency across the two studies suggests that any issues with the reliability were not caused by the sample, the data collection environment, or the pandemic.

General Discussion

The purpose of the current chapter was to examine the associations between different aspects of autobiographical memory, including memory accuracy, memory specificity, recollective experience, memory functionality, rumination, and five executive functioning processes (e.g., mental flexibility, visuospatial learning, inhibition, and forward and backward verbal learning). Across both studies, we found correlations between the brooding, depression, and reflection subscales of the RRS, and this finding is in line with the literature (Nolen-Hoeksema & Morrow, 1991). Whereas self-reflection (i.e., paying attention to one's thoughts and emotions) is generally known to encourage problem-solving behaviours and resilience in the face of life's adversities (Crane et al., 2019; Treynor et al., 2003), people with a negative view of the self can often engage in reflection differently (Ingram et al., 1998). Instead of learning from their past mistakes, people who are self-critical tend to focus on their failures and ruminate on how they could have acted differently. This more maladaptive form of reflection can increase brooding tendencies, which may, in turn, heighten depressive symptoms.

When we compared the correlations between the three subscales of the RRS, the correlation between the brooding and depression items was stronger than the correlation between the brooding and reflection items, (zs = 5.233 – 5.748, ps $< .001$), suggesting a closer relationship between the brooding and depression subscales. Support for the association between brooding and depression can be found in previous studies as brooding has consistently been shown to be a strong predictor of depression in children and adolescents

(Burwell & Shirk, 2007; Verstraeten et al., 2011). For instance, Gibb and colleagues (2012) examined the role of brooding in children who are at risk for depression. During the first session, the authors measured the children's brooding tendencies by using the RRS (Treynor et al., 2003) and measured their depression levels using the Children's Depression Inventory (Kovacs, 1981). After a 20-month interval, the authors re-evaluated the children's depression levels and observed that children with higher brooding tendencies exhibited increased levels of depressive symptoms compared to children with lower brooding tendencies. Brooding has also been found to mediate the relationship between suicidal ideation and self-criticism, as well as between emotional abuse during childhood and depression (O'Connor & Noyce, 2008; Raes & Hermans, 2008).

In terms of the correlation between the three subscales of the TALE, there were medium correlations between the directing behaviour and self-continuity functions of the TALE observed across both studies, and this finding is in line with Bluck and colleagues (2005). Participants who were more likely to use their autobiographical memories to learn from their past behaviours also reflected on their memories to think about how much they have changed or stayed the same over time, which contributes to the formation of their self-identity (Bluck & Alea, 2011). Similar results were also found between the social bonding and directing behaviour functions of the TALE. Across both studies, participants who were likely to think back on their past memories as a means to guide their present or future actions were also more likely to use these memories in the context of social relationships. Overall, our findings suggest that the functions of autobiographical memory work together to maintain the overall wellbeing of an individual (Bluck et al., 2005).

When examining the correlations between five executive functioning processes, we only found associations between the forward and backward verbal learning aspects. Although both processes are governed by working memory, they measure slightly different aspects of working memory and this difference may explain why only medium associations was found between the scores of the Forward and Backward Digit Span task (Alloway et al., 2009; Cornoldi et al., 2014). Whereas the Forward Digit Span task measures the immediate recall of information, the Backward Digit Span task is a more complex task that demands more executive resources for it requires the re-ordering of the sequence of the digits presented (Hester et al., 2004). Support for the dissociation between the forward and backward verbal learning processes also stems from neuropsychological studies. Ghaleh and colleagues (2019) showed that a low-effort task, such as the forward digit span task, only resulted in activations in the posterior superior temporal gyrus, whereas a high-effort task, such as the backward digit span task, would often result in the activations in other brain areas, such as the somatosensory cortex, premotor cortex, and primary motor cortex.

When we examined the correlations between the different aspects of memory, both studies revealed a relationship between memory functionality and rumination. Although it is widely known that most people use their autobiographical memories for directing behaviour, social bonding, maintaining one’s sense of self over time, and emotion regulation purposes (Bluck, 2003; Bluck et al., 2005; Pillemer, 2009; Williams et al., 2015), some people, particularly those prone to rumination, tend to reflect on their autobiographical memories in a more maladaptive manner. They tend to dwell on the negative aspects of an event and engage in a form of counterfactual thinking by thinking about how they could have acted differently. Sometimes, they can also go the extra mile and think about the lack of change they see in themselves. For example, items, like “When I am concerned about whether I am still the same type of person that I was earlier” from the self-continuity subscale of the TALE, can invoke brooding behaviours and can make it very difficult for ruminators to move past their mistakes (Gover, 2011). This notion may explain why the brooding aspect of rumination and the self-continuity aspect of memory functionality were weakly correlated.

It is possible that this intense self-focus that ruminators possess (i.e., worrying about whether they could have behaved differently in a certain situation, whether they had changed or stayed the same over time, etc.) can often lead to the development of a negative view of oneself, and, in turn, lead to the development of depression. For instance, Beck's Cognitive Model of Depression (1967) suggests that depression is characterised by three main features: a negative view of the self, the future, and the world. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychiatric Association, 2013) further supports Beck's model by suggesting that negative self-perception is among the key symptoms of depression. Although we did not explicitly measure the level of depressive symptoms in our participants in either studies, it is possible that participants with higher depressive symptoms (as indicated by higher scores on the depression items of the RRS) also reported higher ratings on the self-continuity subscale of the TALE, such as "When I am concerned about whether I am still the same type of person that I was earlier" or "When I want to understand how I have changed from who I was before" compared to those with lower depressive symptoms. This observed pattern can explain why we found an association between the depression items of the RRS and the self-continuity function of the TALE.

Whereas the brooding and depression aspects are generally considered to be maladaptive, reflection is often considered as a more adaptive form of rumination. According to Treynor and colleagues (2003), reflective rumination is defined as "a purposeful turning inward to engage in cognitive problem solving to alleviate one's depressive symptoms". Across both studies, we found that participants not only reported using their memories to understand their emotions and behaviours, but they are also using their memories for their personal growth. By evaluating their beliefs from past behaviours, they were able to learn from their past mistakes and form a strong self-identity. This notion can explain why participants who gave higher scores for the reflection items of the RRS also gave higher scores for the self-continuity function of the TALE.

Apart from the correlations between the memory functionality and rumination, we also found a relationship between recollective experience and the directing behaviour function of the TALE. According to Bluck (2003), people use their autobiographical memories to reflect on their past behaviours and they use the lessons learnt to guide their present and future actions. Our findings expand on this idea, suggesting that simply recalling our past behaviours is not merely enough; we need to also be able to relive these experiences. The ability to relive our memories is a defining feature of autobiographical memory (Rubin, 2005, 2006). When participants in our studies reflected on their past behaviours to learn from their mistakes, they likely pictured these events in their mind and re-experienced the context along with the emotions that they felt. The following memory is an example that was provided by one of our participants:

"When I got constructive feedback, it was delivered in a very strict tone from my director within the first 3 months of my first job. It was related to the aesthetics update of a PPT slide for a weekly status report. As I was new and did not create the initial deck, I was not accustomed to the specific areas that required weekly updates. Therefore, when I got 'scolded' for it, it made me feel really bad but it also made me more determined to not make that mistake again."

Based on the above-mentioned description, it is evident that this participant relived an experience where they had felt embarrassed. They could remember details surrounding the event, such as creating Power Point slides for a weekly report, getting scolded from their superior for not preparing the slides according to the aesthetics required, and feeling embarrassed afterwards. However, they were determined to not repeat their error in the future.

Besides the associations between rumination and memory functionality and recollective experience and memory functionality, the remaining aspects of memory, such as memory specificity, memory accuracy, and the executive functioning processes, were largely independent of each other and of the afore-mentioned aspects. The dissociation between memory accuracy and recollective experience aspects of memory found in the present study is supported by the findings of Talarico and Rubin (2003). In their study, students from Duke University were asked to recall a flashbulb memory (i.e., the terrorist attacks of September 11, 2001) and were asked to rate their memory on the several characteristics such as the emotions they had felt, the vividness of the memory, belief in the accuracy of their memory, and more. Participants were tested again after a 1-week, 6 weeks, and 32-weeks interval. The consistency of their narrative across all four sessions were coded by the experimenters and was used as a proxy of memory accuracy. Similar to the findings of the present study, the authors found that participants belief in accuracy was correlated with the measures of recollection such as emotion ratings, but not with measures of consistency.

Furthermore, the finding that memory accuracy does not relate to executive functioning processes, such as verbal learning and visuospatial learning, contradicts the findings of Janssen and colleagues (2015). In their study, participants completed a diary study with two sessions: a recording session and a recall session. During the recording session, participants recalled a recent event which had occurred in the last three days and provided details surrounding the event (e.g., what happened, who was involved, when the event occurred). After an interval ranging from 2 to 46 days, participants attended the second session where they were given cues and were asked to recall the three details provided in the first session. The consistency between the answers provided across the two sessions was operationalized as a measure of memory accuracy. Besides the diary sessions, participants also completed verbal and visuospatial tasks, such as the Digit Span Task and the Corsi Block

Task. Janssen et al. (2015) found small but significant associations between scores on the diary study and the scores on the executive functioning tasks after accounting for event characteristics, such as importance and emotional intensity of the event and the time between the recording and recall of the event. Although the findings of Janssen et al. (2015) suggests that memory accuracy and some aspects of executive functioning, such as verbal learning and visuospatial processing, are related, the small effect sizes reported in their study suggests that these associations are weak. Given that the present studies found no associations between these aspects, future studies should conduct further research to determine the exact nature of the relationship between memory accuracy and executive functioning.

Although findings from the current chapter have provided valuable insights into the relationships between different aspects of autobiographical memory, they possess several limitations. For instance, the alpha criterion (.05/91 = .005) applied across Studies 1 and 2 may have been overly conservative, potentially masking some weak (but meaningful) associations observed across the different aspects of autobiographical memory (see General Discussion for more details).

Conclusions

In the current chapter, we examined whether different aspects of autobiographical memory (i.e., memory accuracy, memory specificity, recollective experience, memory functionality, rumination, and five executive functioning processes) are related. Across two cohorts, we found moderate intercorrelations between the subscales of the TALE, the subscales of the RRS, and the forward and backward verbal learning processes. Whereas some aspects of autobiographical memory, such as functionality, recollective experience, and rumination, were related, other aspects, like memory accuracy, memory specificity, and executive functioning, appeared to function more independently.

Chapter 3: Exploring the Heritability of Individual Differences in Autobiographical Memory Among Malaysian Twins

Autobiographical memory is the system that stores and consolidates information from an individual's life experiences (Conway & Pleydell-Pearce, 2000). Although the process of encoding and retrieval of autobiographical memories appears to be a universally human experience, there are individual differences in how people recall their memories, and these differences have been linked with a range of psychological disorders. For example, when asked to retrieve specific memories (i.e., memories of events that happened at a specific place and time and lasted less than a day), people with depression often retrieve overgeneral memories which are either categorical in nature (e.g., going to university, meeting a friend) or have lasted for an extended duration of time (e.g., family vacations; Liu et al., 2013; Williams et al., 2007). People with post-traumatic stress disorder (PTSD), on the other hand, tend to report heightened emotions and strong feelings of reliving when remembering traumatic events (Hall et al., 2018; Brewin et al., 2010).

Neuropsychology and functional imaging studies have shown that components of the autobiographical memory process have been linked to neural substrates, such as the visual cortex, hippocampus, and amygdala. Deficiencies, or less activity, in one of these brain regions leads to corresponding deficiencies in the content or phenomenology of autobiographical memories (Rubin, 2005, 2006). The amygdala, for instance, is implicated in the processing of emotional events, and lesions to the amygdala have been linked to deficits in remembering emotional memories (Amaral et al., 1992; Buchanan et al., 2005). When asked to retrieve remote autobiographical events, people with damage to their amygdala recalled fewer unpleasant events compared to healthy controls. In addition, their unpleasant memories were also rated as less intense than those reported by the control group (Buchanan et al., 2005). Deficits in autobiographical memory retrieval is also evident in patients with hippocampal damage. In a study by Herfurth et al. (2010), participants with hippocampal damage were asked to retrieve autobiographical events from different lifetime periods such as childhood/adolescence, early adulthood, and recent events. The authors reported that these individuals had difficulties retrieving specific details such as the time and place of the events, and this impairment extended across all stages of life.

Although numerous studies have examined the cognitive and biological factors that may lead to deficits in memory retrieval (Rubin, 2005; Rubin, 2006; Williams, 2006; Williams et al., 2007), little research has been conducted to examine the gene-environment interactions that may contribute to these deficits. Given the lack of research in this area, the goal of the present study was to enhance our understanding of the biological basis of memory by examining whether the six aspects of autobiographical memory (i.e., memory specificity, memory accuracy, rumination, executive functioning, recollective experience, and memory functionality) are heritable. We conducted a twin correlational study among monozygotic and dizygotic Malaysian twin pairs to obtain an optimal estimation of the genetic and environmental influences on autobiographical memory (van Dongen et al., 2012).

The Basic-Systems Approach

According to the Basic-Systems Approach, autobiographical memories are formed by the interaction of several lower-level systems, such as vision, emotion, and more (Rubin, 2005, 2006). These basic systems possess their own function and neural substrates. Evidence for the biological basis of these systems stems from functional magnetic resonance imaging (fMRI) studies, Positron Emission Tomography (PET) studies, and neuropsychological case studies.

Among the basic systems outlined by Rubin (2006) is recollective experience. This basic system is a fundamental aspect of autobiographical memory as it enables an individual to re-experience past events during retrieval. Although limited, studies have shown that there are neural substrates underlying recollective experience (e.g., Daselaar et al., 2008). At the beginning of Daselaar and colleagues' fMRI study, participants were blindfolded to avoid visual imagery processing for external stimuli. Participants began the experiment by retrieving a specific memory for different cue words which were presented auditorily. They were given 12 seconds to retrieve a memory (i.e., memory access phase) and an additional 12 seconds to think about the details of the memory (i.e., memory elaboration phase). Upon retrieving details, participants rated each event on the recollective experience using a 4-point Likert scale. When providing ratings of reliving, the authors observed stronger activations in the right inferior frontal and extrastriate cortices which are associated with recollection (Markowitsch, 1995) and visual imagery, respectively.

The second system, known as the self-referential system, also plays an important role during memory retrieval. This system facilitates self-referential processing which involves relating information from the external environment to oneself (Northoff, 2006). The self-referential system works together with language (a higher-order system) to form an individual's life narrative. The biological basis of the self-referential system is one that is well-established (Gusnard et al., 2001; Kelley et al., 2002; van der Meer et al., 2010). For example, in a study by Cabeza and colleagues (2004), participants were asked to capture images of locations at their university campus (e.g., library, auditorium) and were later shown images that were taken by other people. In a subsequent recognition task, participants were presented with both sets of images and were required to recognize the images that they had taken. There were stronger activations in the medial prefrontal cortex (mPFC) when participants recognized photos that were taken by themselves compared to photos that were taken by other people (also see St Jacques et al., 2011). Deficits in self-referential processing can also be observed in people with damage to the mPFC. When asked to retrieve a specific past memory in response to a neutral cue, people with damage to the mPFC produced fewer self-referential information compared to healthy adults (Kurczek et al., 2015).

The visual imagery system, on the other hand, allows individuals to re-experience events by recreating the different visual aspects of the events in their mind. The specificity and vividness of autobiographical memories during retrieval is often dependent on this system. Like the recollective experience and self-referential systems, visual imagery is also known to have its own neural substrates (Rubin & Greenberg, 1998). Greenberg and Rubin (2003) investigated whether damage to areas involving visual memory would affect memory retrieval. In their study, they examined people with visual memory deficit amnesia (VMDA) – an impairment brought about by damage to the occipital cortex. Individuals with VMDA were able to draw images of objects they were shown but had difficulties drawing and naming said object from memory. The authors further proposed that although people with VMDA had unimpaired vision, visual information for long-term memories was lost.

Finally, the emotion system is known to influence the vividness of autobiographical memories during the encoding phase. Holland & Kensinger (2010) proposed that emotional memories tend to be recalled with more details because people pay more attention to emotional events than neutral events. People also remember positive events more easily compared to negative events, because positive memories are richer in detail and feel psychologically closer to an individual compared to negative events (Demiray & Janssen, 2015; Van Boven et al., 2010). There are many brain regions that are implicated in the recall of emotional events and among them are the amygdala (Markowitsch et al., 2000). In an fMRI study conducted by Botzung et al. (2010), fans of basketball watched a segment of a match between their favourite team and its rival. Once the video ended, they were given a recognition task where they had to determine whether they had seen segments of plays from the game. Half of these clips originated from the video whereas the remaining half were from parts of the game participants did not see. Participants also rated these memories on the emotional intensity. The amygdala showed stronger activations for clips with higher emotionality scores compared to clips with lower emotionality scores. Deficits in emotional remembering can also be observed in people with damage to their right hemisphere (Cimino et al., 1991). Cimino et al. (1991) asked patients with right hemispheric damage (RHD) to retrieve specific autobiographical memories in response to 8 neutral and 8 emotional cues. The emotionality of the memories was rated by participants and was later rated by the researchers. Compared to the control group, patients with damage to the right hemisphere retrieved memories with reduced specificity that were less emotional.

Autobiographical memory is a multifaceted and complex construct as it involves sight, smell, sounds, taste, and kinesthesis. The formation of autobiographical memories is therefore believed to be a result of the interaction of the basic systems proposed by Rubin (2006). Daselaar and colleagues (2008) provided further evidence for Rubin's model by mapping the time course of autobiographical memory retrieval. As mentioned previously, there were three phases in their study: memory access, memory elaboration, and subjective ratings. The memory access phase involves searching for memories in the autobiographical knowledge base upon cue presentation. During this phase, the authors reported stronger activations in the hippocampus which is linked to recollective experience (Cabeza et al., 2004). When participants had a memory in mind, they pressed a button which resulted in stronger activations in the motor cortex. Upon pressing the button, participants elaborated on the memory they retrieved, which activated the visual cortex more strongly. After the elaboration phase, participants rated the memories on the emotionality (activating the amygdala) and recollective experience (activating the visual and extrastriate cortices more strongly). The time course outlined by Daselaar and colleagues (2008) demonstrates how the basic systems interact at different stages of retrieval to create autobiographical memories as we know it.

The Basic-Systems Approach is a well-defined model that explains the mechanisms (i.e., basic systems) underlying the encoding, consolidation, and retrieval of autobiographical memory (Rubin, 2006). However, it is possible for individual differences to exist within these lower levels. An example of individual differences that exist in the vision system is aphantasia. Aphantasia is characterized by the inability to create visual images in one's mind (Zeman et al., 2015; Zeman et al., 2020). Whereas some people can hold a visual image in their mind, aphantasics are unable to engage in any visual imagery whatsoever. Besides vision, researchers have also found individual differences in the recollection system of autobiographical memory. For instance, people with Highly Superior Autobiographical Memory (HSAM) tend to recall vivid details such as specific dates and people they were with when recalling a past event (Le Port et al., 2012). In contrast, people with Severely Deficient Autobiographical Memories (SDAM) often provide fewer internal details and report weaker feelings of reliving during memory retrieval (Palombo et al., 2015). The Basic-Systems Approach posits that autobiographical memories have a biological basis as our memories are formed by basic systems with distinct neural substrates. These basic systems may be influenced by genetic factors that are not well understood. Therefore, examining the heritability of autobiographical memory would help provide an insight into the genetic underpinnings of individual differences in autobiographical memory.

An Overview of Heritability

Genes are known as the basic units of life as they contain essential information required for the development and maintenance of a living organism (Pierce, 2012). With the exception of some viruses, the genetic material for all life on Earth is stored in the form of DNA or deoxyribonucleic acid, which is a molecule containing a long chain of polynucleotides, such as phosphate, sugar, and nitrogenous bases (e.g., adenine, thymine, cytosine, and guanine). A DNA molecule takes up the form of a double helix as the nitrogenous bases form base pairs (i.e., adenine-thymine and cytosine-guanine) that are held together by hydrogen bonds.

According to the Human Genome Project (International Human Genome Sequencing Consortium, 2004), the human genome is made up of 3 billion base pairs of DNA. Over the course of 13 years, researchers from the project have identified close to twenty-five thousand genes which are organized into two sets of 23 chromosomes. When genes are passed down from one generation to another, the progeny inherits a set of 23 chromosomes from each parent. Whereas 99% of genes that code for universal traits (e.g., number of limbs) are shared across human beings, less than 1% of genes interact with the environment to produce variations in phenotypes (i.e., observable characteristics that occur as a result of gene expression). For instance, the gene that codes for eye colour can be expressed differently as some people have dark brown eyes whereas others have blue eyes. This difference in gene expression is brought about by alleles which are alternate versions of a gene within a given locus (Pierce, 2012). Most genes have two alleles that code for a certain trait, and each allele is inherited from a parent.

The heritability of a given trait was initially defined as the proportion of phenotypic variation in a given population that can be explained by genetic factors (Falconer, 1960; Lynch & Walsh, 1998). However, more recent studies have put forward two separate definitions of heritability. Whereas broad-sense heritability (H^2) is known as the proportion of phenotypic variation (σ_P^2) attributable to genetic factors (σ_G^2) such as additive genetics, epistatic effects (interactions between alleles across different loci), and dominance (interactions between alleles within a given locus), narrow-sense heritability (h^2) is an estimate of the proportion of phenotypic variation explained only by additive genetics or σ_A^2, which refers to the process by which genes from parents influence the phenotypic variation observed in children (Mayhew & Meyre, 2017; Visscher et al., 2008). The formulae for the two kinds of heritability are included in Table 3.1.

Table 3.1

Formulae used to calculate estimates of broad-sense and narrow-sense heritability.

Types of Heritability	Formulae
Broad-sense heritability (H^2)	$\frac{\sigma_G^2}{\sigma_P^2}$
Narrow-sense heritability (h^2)	$\frac{\sigma_A^2}{\sigma_P^2}$

Although methods, such as family studies, adoption studies, and genome-wide association studies (GWAS), have been used to estimate heritability over the past decades (Gialluisi et al., 2021; Mayhew & Meyre, 2017), there is one design that is most commonly used in heritability research: twin studies. Twin studies are particularly useful in estimating the heritability of a given trait as monozygotic twins share 100% of their genes, whereas dizygotic twins only share about 50% of their genes. In these twin studies, an ACE model is constructed by comparing the correlations between monozygotic and dizygotic twin pairs.

The ACE model suggests that the phenotypic variance of any given trait can be explained by three main factors: additive genetics (A), common environmental factors (C), and unique environmental factors (E). Whereas additive genetics is known as the influence of genetic factors on a particular phenotype (Neale & Cardon, 1992; Root et al., 2010), common or shared environmental influences (*C*) are environmental factors that contribute equally to the monozygotic twin pair and dizygotic twin pair resemblances. Some examples of shared environmental influences include socioeconomic status and rearing environment (Vernon-Feagans et al., 2016). Unique or nonshared environmental factors (*E*), on the other hand, are events that are experienced by one twin but not the other (Neale & Cardon, 1992). According to the ACE model, the heritability of a certain trait can be estimated using the following formula:

$$h^2 = \frac{A^2}{A^2 + C^2 + E^2}$$

The Heritability of Autobiographical Memory

The CaR-FA-X model was put forward by Williams and colleagues (2007) to explain the mechanisms underlying overgeneral memory retrieval. They suggested three factors that may contribute towards the overgeneralization of autobiographical memories: capture and rumination, functional avoidance, and impaired executive functioning. Capture and rumination occur when an individual engages in ruminative thinking and disrupts the memory retrieval process. Functional avoidance, on the other hand, occurs when people avoid retrieving specific memories as a mean of affect regulation. The third mechanism, impaired executive functioning, refers to the inability to retrieve specific memories from the autobiographical knowledge base due to deficits in the executive functioning processes (Conway & Pleydell-Pearce, 2000).

Although the current knowledge of the heritability of autobiographical memory is limited, there is evidence to suggest that the rumination mechanism of the CaR-FA-X model is moderately heritable. For instance, Johnson et al. (2014) asked adult twins to complete several rumination questionnaires, such as the Ruminative Response Scale (RRS) and the Rumination-Reflection Questionnaire, and found that rumination had heritability estimates ranging from 37% to 41%. Apart from rumination, studies have also shown that some executive functioning processes such as inhibitory control and spatial working memory are moderately influenced by additive genetics (Stins et al., 2004). Polderman and colleagues (2009) asked young children and adolescents to complete the Stroop task and found that inhibitory control was heritable, with estimates ranging from 36% to 51%. Besides inhibitory control, neuroimaging studies have also shown that spatial working memory is highly heritable (Ando et al., 2001; Singer et al., 2006; Zhou et al., 2018). For instance, white-matter integrity which is essential for spatial working memory was found to be highly heritable and is also reported to be a genetic marker for schizophrenia (Bohlken et al., 2016; Goldman-Rakic & Leung, 2002). Because studies have shown that rumination and executive functioning mechanisms of the CaR-FA-X model are heritable, a further exploration on the heritability of different aspects of memory would help us better understand the mechanisms underlying overgeneral memories at a genetic level.

Although limited, there is evidence to suggest that genetic factors may influence the specificity of autobiographical memories during retrieval. For instance, the Apolipoprotein E (APOE) gene is responsible for lipid transport in humans (Verghese et al., 2011). The ε4 allele of this gene has been identified as a strong risk factor for Alzheimer's disease (Okuizumi et al., 1994) and carriers of this allele have also been found to possess smaller hippocampal volumes compared to non-carriers (O'Dwyer et al., 2012). Given the effects of the ε4 allele on the hippocampus, researchers have tried to better understand the effects of the gene on a more cognitive level. Knoff and colleagues (2024) recruited two groups of cognitively healthy older adults: carriers of Apolipoprotein E ε4 allelle (otherwise known as APOE4) and non-carriers of APOE4. Participants were asked to retrieve a specific autobiographical memory for events which occurred within the last five years in response to a single-word cue (20 cues in total). The authors found that carriers of the APOE4 allele retrieved fewer specific memories compared to non-carriers (also see Acevedo-Molina et al., 2023). In a similar study, Grilli et al. (2018) asked healthy middle-aged to older adults to retrieve specific autobiographical memories and found that carriers of the APOE4 allele retrieved autobiographical memories with fewer internal details compared to non-carriers of APOE4.

The Catechol-O-methyltransferase (COMT) gene Val^{158}Met polymorphism is also a gene known to produce individual differences during autobiographical memory retrieval (Tõugu et al., 2022). In their study, Estonian children who were between 9 and 13 years old were required to retrieve their earliest autobiographical memory. The children were then classified into one of three genotype groups: Val/Val, Val/Met, Met/Met. The authors found that children who were Val/Met heterozygotes were less likely to provide details for the emotional events they described. Furthermore, Tõugu et al. (2022) also reported that girls who were Val/Met heterozygotes retrieved more specific details when describing their earliest memory compared to boys who were Val/Met heterozygotes. Met/Met homozygotes, on the other hand, tended to report more specific details when describing their autobiographical memories compared to Val/Met heterozygotes (Tõugu et al., 2016).

Because genes are the basic units of heredity, and the presence (or absence) of these genes (or alleles) result in individual differences in autobiographical memory, these studies provide a strong basis to examine the heritability of individual differences across different aspects of autobiographical memory.

The Present Study

In the previous chapter, we examined whether six aspects of autobiographical memory (e.g., memory accuracy, memory specificity, recollective experience, functionality, rumination, and executive functioning) were related. Across two studies, participants completed a series of tasks in a test battery which measured the different aspects of memory. Our findings suggest that not all aspects of autobiographical memory are related. Whereas memory functionality and rumination were related, memory accuracy, memory specificity, recollective experience, and executive functioning remained independent.

In the present study, we will examine the heritability of individual differences across six aspects of autobiographical memory described in the first study of the previous chapter. The heritability of autobiographical memory can therefore be defined as the proportion of variance observed across six aspects of memory (i.e., memory specificity, memory accuracy, rumination, executive functioning, recollective experience, and memory functionality) that can be explained by genetic influences, whereas the remaining variation in memory traits can be accounted for by environmental factors (either common or non-shared environmental influences). We expect the findings of this chapter to further contribute to the biological perspective of autobiographical memory.

As described in the previous chapter, monozygotic and dizygotic twin pairs watched a video of a simulated theft and later answered a recognition test measuring accuracy for items in the video. In between, participants retrieved 10 personal events with the help of cues and rated these memories on recollective experience. They also completed questionnaires measuring functionality and rumination, and with five executive-functioning tasks measuring five different processes of executive functioning. To our knowledge, this is the first study to investigate the influence of additive genetics and environmental factors on the heritability of autobiographical memory. Given that autobiographical memories are formed by lower-level systems that possess their own functions and neural substrates and that monozygotic twins share 100% of their DNA (compared to dizygotic twins who share approximately 50% of their DNA) which are assumed to contribute to the development of these neural substrates, we expect monozygotic twins to perform more similarly than dizygotic twins on the different tasks representing the autobiographical memory aspects (Prescott & Kendler, 1995; Rubin 2005, 2006).

Method

Participants

As stated in Study 1 of Chapter 2, 69 pairs of monozygotic and 53 pairs of dizygotic twins from the Nottingham Malaysian Twin Registry had been recruited. The data reported in this chapter is the same, but where we examined the associations between individual differences in Chapter 2, we examined the heritability of these individual differences in this chapter.

The datasets of 13 pairs of monozygotic twins and 12 pairs of dizygotic twins were, however, removed because at least one member of the pair performed poorly on the recognition task (i.e., they obtained a score of 10 out of 20), was clinically diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) or Major Depressive Disorder (MDD), had a learning disability, was raised in a separate home, or obtained scores below baseline for the different executive functioning tasks (i.e., they obtained a block span of 1 of 9 for the Corsi Block task, an accuracy score of less than 25% for the Flanker task, a perseverative response rate of 0% for the Berg's Card Sorting task, or an accuracy score of less than 20% for the Forward Digit Span or Backward Digit Span tasks). We also excluded the data from one pair of monozygotic and one pair of dizygotic twins because they completed the experiment twice. Additionally, the datasets of two pairs of monozygotic twins and one pair of dizygotic twins were removed because the program running the executive functioning tasks crashed during the completion of the tasks.

After the exclusion of outliers, our sample comprised 53 monozygotic and 39 dizygotic twins (48 males and 136 females) who were between 16 and 53 years old (*M* =

25.54*, SD* = 6.74). The present study was approved by the Science and Engineering Research Ethics Committee (SEREC) of the University of Nottingham Malaysia (AFCM210319).

Materials and Procedure

Like Study 1 of Chapter 2, participants joined a Google Meet session before the experiment began. They were then given an online information sheet, consent form, and demographics form to answer. Upon providing consent, the experiment began. Participants first watched a six-minute video on YouTube of a staged burglary (Takarangi et al., 2006). They then completed an AMT (Williams & Broadbent, 1986) where they retrieved specific memories for ten cue words (i.e., sad, river, angry, fire, love, book, happy, city, fear, and flower) and subsequently rated each memory on their recollective experience. Later, the researchers would score these memories on specificity.

Upon completing the AMT, participants answered a 20-item recognition test that measured accuracy for items in the afore-mentioned video. Participants also completed the RRS (Nolan Hoeksema & Morrow, 1991), which measured rumination, and the TALE (Bluck & Alea, 2011; Bluck et al., 2005), which measured memory functionality. Upon completing the RRS and the TALE, participants were given a five-minute break.

After the break, participants completed the Berg's Card Sorting task (Berg, 1948) which measures mental flexibility, the Corsi Block task (Corsi, 1972) which measures visuospatial learning, the Flanker task (Eriksen & Schultz, 1979) which measures inhibition, and the Forward and Backward Digit Span tasks (Wechsler, 2008) which measures verbal learning. More details about the questionnaires, tests and tasks can be found in the Method section of Study 1 of Chapter 2. The experiment took approximately 120 minutes to complete. At the end of the session, participants received a renumeration of RM 40 for their time.

Results

Exploratory Factor Analyses

Before estimating the additive genetics (A), common environmental (C), and unique environmental (E) components of heritability, an exploratory factor analysis was conducted to examine the factor structures underlying three aspects of memory (i.e., memory accuracy, memory specificity, and recollective experience). Each factor was extracted using the Principal Component Analysis method with Varimax rotation and Kaiser normalization. Only eigenvalues more than 1.0 and factor loadings more than 0.3 were interpreted.

This analysis was motivated by the findings of previous studies that have shown that memory accuracy, memory specificity, and recollective experience are all related aspects of autobiographical remembering. For example, Scoboria et al. (2015) showed that belief in accuracy was linked with stronger feelings of reliving, and Hallford et al. (2021) reported that highly specific memories are often accompanied with stronger feelings of reliving. Additionally, given the lack of significant correlations between the three aspects in Chapter 2, a factor analysis was conducted to identify shared variances and to form composite scores that could improve the reliability of ACE estimates. Findings from our analysis revealed that three aspects of memory did not load onto a common factor, $\chi^2(3) = 4.52$, $p = .210$.

We conducted a separate exploratory factor analysis to investigate the relationship between the five executive functioning processes (i.e., mental flexibility, visuospatial processing, inhibition, and forward and backward verbal learning). Like the previous analysis, the present analysis was motivated by evidence suggesting that these cognitive processes are related (Viana-Sáenz et al., 2021). The factor loadings for the different executive functioning tasks are reported in Table 3.2. The analysis revealed a two-factor model which accounted for 54.44 % of the overall variance, $\chi^2(10) = 65.60$, $p < .001$. Three variables namely visuospatial processing and forward and backward verbal learning processes all loaded onto a single factor and had scores ranging from 0.586 to 0.822. Because these tasks require the usage of short-term memory, Factor 1 was therefore conceptualised as a single factor named working memory capacity. Factor 2, on the other hand, was only made up of one variable namely inhibition which had a loading of 0.826. The mental flexibility process of executive functioning, however, did not load on any of the two factors.

Table 3.2

Factor loadings obtained from an exploratory factor analysis conducted for the five executive functioning processes.

Memory Characteristics	Factor Loading	
	1	2
Forward verbal learning	.822	.106
Backward verbal learning	.746	.135
Visuospatial processing	.586	--
Inhibition	--	.826
Mental flexibility	-.136	-.638

Note. Factor loadings reported are sorted by the largest to the smallest values of variance explained.

Confirmatory Factor Analyses

To confirm the factor structure for the 15-items of the RRS, we ran a confirmatory factor analysis using the R *lavaan* package (Rosseel, 2012) included in JASP. A three-factor model was confirmed, and this finding is in line with previous research (Shin et al., 2015).

Twelve items loaded onto the first factor measuring depressive symptoms, five items loaded onto the second factor measuring brooding tendencies, and five items loaded onto the third factor measuring reflection tendencies. The fit of the model was deemed appropriate by indices such as the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA), CFI = 0.800, RMSEA = .084. Moreover, the Cronbach's alphas of the brooding, depression, and reflection factors were also high (α = .725, .861, and .710).

Next, we conducted a confirmatory analysis to examine the factor structure underlying the 15-items of the TALE. Our analysis revealed three main factors, which is in line with the findings of Bluck and Alea (2011). Five items loaded onto the first factor assessing the directive function, another five items loaded onto the second factor assessing the social bonding function, and the final five items loaded onto a third factor assessing the self-continuity function. The fit of the model was appropriate (CFI = 0.874; RMSEA = .080) and the Cronbach's alpha for the directive, social bonding, and self-continuity functions were high (α = .698, .773, and .809).

Heritability of Autobiographical Memory

We have seen earlier that monozygotic twins share 100% of the genes, whereas dizygotic twins share only 50% of their genes (Neale & Cardon, 1992) and both groups share a common environment, as twins often grow up in the same household (also see the Equal Environments Assumption by Scarr & Carter-Saltzman, 1979). The correlation between monozygotic twins (r_{Mz}) and between dizygotic twins (r_{Dz}) can therefore be expressed as follows:

$$r_{Mz} = A + C$$

$$r_{Dz} = \frac{A}{2} + C$$

Because the environment does not differ systematically for monozygotic and dizygotic twins, any difference in the phenotypic variance observed between the monozygotic and dizygotic pairs should be due to genetic factors (Falconer, 1960). That being said, the influence of additive genetics (A) on a certain trait can be estimated by using the following formula:

$$A = 2(r_{Mz} - r_{Dz})$$

On the other hand, the influence of shared environmental factors (i.e., the variance shared between monozygotic and dizygotic twins which cannot be explained by additive genetics) on a given trait can be expressed as follows (Haworth et al., 2008):

$$C = r_{Mz} - A$$

Finally, because the total variance explained by additive genetics, common environmental, and unique environmental factors must equal to 1 (Neale & Cardon, 1992; Plomin et al., 2008), unique environmental factors (i.e., factors that make monozygotic twins different or measurement error) can simply be calculated by the following formula:

$$E = 1 - r_{Mz}$$

Before we conducted the correlations to compare the scores between the different zygosity groups, we combined the scores from the three subscales of the RRS (i.e., brooding, depression, and reflection). Because all the items on the RRS were measured on the same scale, we added the scores from each subscale and formed the composite variable rumination. The composite variable memory functionality was also formed by combining the scores from the three subscales of the TALE (i.e., social bonding, directing behaviour, and self-continuity). Next, the scores from the Forward Digit Span, Backward Digit Span, and the

Corsi Block tasks were transformed to standardized z-scores and combined to form a single score for the variable working memory capacity.

Previous studies have shown sex-related differences in autobiographical memory retrieval (Compère et al., 2018; Davis, 1999; Grysman & Hudson, 2013). Specifically, women tend to retrieve autobiographical memories that are more emotional, richer in detail, and are perceived as more personally significant than memories retrieved by men (Grysman & Hudson, 2013; Pillemer et al., 2003; Stapley & Haviland, 1989). Because sex can act as a potential confounding variable when comparing the correlations between monozygotic and dizygotic twins, the ACE estimates were only calculated using the correlations of dizygotic twins who were of the same sex. Furthermore, a series of Fisher's Z tests were also conducted to determine whether there were differences in the correlations of same-sex dizygotic twins and different-sex dizygotic twins across the different aspects of memory (Lenhard & Lenhard, 2014). Our findings revealed no significant differences between the two groups (zs = -1.749 – 2.158, ps > .05).

Sixteen bivariate correlations across the two zygosity groups were calculated for the aspects of autobiographical memory: memory specificity, memory accuracy, recollective experience, rumination, memory functionality, and the three assessments of executive-functioning processes (i.e., mental flexibility, inhibition, working memory capacity). The scatter plots for the scores obtained by the different zygosity groups across the different tasks are presented in the Appendix section (Figures A2 to A9).

For the variable memory specificity, we found medium correlations between the scores of monozygotic twins, $r(51) = .494$, $p < .001$, 95% CI [.259, .674], $R^2 = .244$, and dizygotic twins, $r(27) = .459$, $p = .012$, 95% CI [.112, .707], $R^2 = .211$. For the measure of memory accuracy, we found weak to moderate correlations between the scores of monozygotic twins, $r(51) = .390$, $p = .004$, 95% CI [.134, .597], $R^2 = .152$, and dizygotic twins, $r(27) = .509$, $p = .005$, 95% CI [.176, .738], $R^2 = .259$. There was also a correlation between the scores of monozygotic twins for the measure of recollective experience, $r(51) = .276$, $p = .045$, 95% CI [.006, .508], $R^2 = .076$. Furthermore, the scores of monozygotic twins were weakly correlated for the measure of rumination, $r(51) = .444$, $p < .001$, 95% CI [.198, .638], $R^2 = .197$. When we applied Bonferroni corrections to account for the multiple comparisons (i.e., .05/16 = .0031), only the within-monozygotic twin correlations for the measure of memory specificity and rumination remained significant.

In terms of the performance of the different zygosity groups on the five executive functioning tasks, we found two significant associations. There was a moderate correlation between the scores of dizygotic twins on Flanker task measuring inhibitory control, $r(27) = .444$, $p = .016$, 95% CI [.093, .697], $R^2 = .197$. Next, we found that monozygotic twin participants perform more similarly across the different working memory capacity tasks, $r(51) = .445$, $p < .001$, 95% CI [.199, .639], $R^2 = .198$. The correlations between the scores of dizygotic twins on the Flanker task no longer remained significant once a Bonferroni correction was applied.

The within-monozygotic and within-dizygotic twin pair correlations for the remaining aspects of memory were not significantly different from 0. The additive genetics (*A*) and the common (*C*) and unique (*E*) environmental contributions for each of these aspects are presented in Table 3.3.

Table 3.3

Cross-twin correlations between monozygotic and dizygotic twins and heritability estimates for the different components of autobiographical memory.

	*r*MZ	*p*	*r*DZ (Same)	*p*	*r*DZ (Diff)	*p*	h^2	*A*	*C*	*E*

Memory Specificity	.494	<.001	.459	.012	.744	.014	0.011	0.070	0.424	0.506
Memory Accuracy	.390	.004	.509	.005	.000	1.000	0.069	-0.238	0.628	0.610
Recollective Experience	.276	.045	.176	.361	.059	.872	0.070	0.200	0.076	0.724
Rumination	.444	<.001	.013	.948	.270	.451	0.606	0.862	-0.418	0.556
Memory Functionality	.180	.198	.104	.591	-.082	.821	0.033	0.152	0.028	0.820
Executive Functioning Tasks										
Inhibition	.140	.317	.444	.016	-.415	.233	0.222	-0.608	0.748	0.860
Mental Flexibility	-.102	.466	-.082	.672	.058	.874	0.001	-0.040	-0.062	1.102
Working Memory Capacity	.445	<.001	.339	.072	.358	.310	0.110	0.212	0.233	0.555

Note. The heritability estimates for each memory component are represented by estimates of additive genetics (*A*), common or shared environmental factors (*C*), and unique or nonshared environmental factors (*E*).

Discussion

In the present study, the heritability of autobiographical memory was investigated by estimating the influence of additive genetics (*A*), common environmental (*C*), and unique environmental (*E*) factors across six aspects (i.e., memory accuracy, memory specificity, recollective experience, memory functionality, rumination, and executive functioning). Because autobiographical memory is known to have a biological basis, we expected the different aspects of memory to be highly heritable. However, most of the twin pair correlations between monozygotic and dizygotic twins were not significant, making comparisons between the groups unreliable. Apart from the lack of significant correlations, we found that recollective experience, rumination, memory functionality, and the mental flexibility process of executive functioning had estimates of common environmental factors (0.076, -0.418, 0.028, and -0.062, respectively) close to or even below 0, further suggesting that the twin pair correlations for these aspects may have been unreliable. Moreover, the correlations between dizygotic twins were larger than the correlations between monozygotic twins, leading to negative values for the additive genetic factors of memory accuracy (A = -0.238) and the inhibition (A = -0.608) processes of executive functioning.

The unreliability of the observations could be due to the relatively small sample size in the present study. Although we initially recruited 244 participants (i.e., 69 pairs of monozygotic and 53 pairs of dizygotic twins), only 53 pairs of monozygotic and 29 pairs of same-sex dizygotic twins remained after excluding pairs where at least one of the twins had a diagnosis or performed below chance level, reducing the power of our study. A larger sample size of 100 eligible monozygotic and 100 eligible dizygotic twin pairs would have provided sufficient power to the study and would, in turn, have increased the reliability of the associations observed. Also, the use of composite scores (i.e., using several measures for one aspect) seems to improve reliability. Single measures, such as inhibition and mental flexibility, yielded lower heritability estimates than composite measures (e.g., rumination and working-memory capacity).

The reliability of cognitive tasks in psychological research is a growing concern and is often referred to as the measurement crisis. Although cognitive tasks, like the Flanker and Inhibition of Return tasks, produce robust within-subjects effects across different populations (Hedge et al., 2018; Pratt & Abrams, 1999), they are often poor measures of individual differences. For example, in a typical Flanker task, there are two conditions (congruent and incongruent) which indicate that there are two sources of error variances in the results. Because inhibition is measured as the difference between the two conditions, inhibition measured by the Flanker task would therefore possess twice the amount of error variance compared to inhibition measured by a different task, increasing the amount of noise in the task. In the context of the present study, a large amount of noise between the congruent and incongruent conditions of the Flanker task could explain why the correlations of the dizygotic twins were found to be larger than the correlations of the monozygotic twins (A = -0.608) for the inhibition process of executive functioning. The correlation for the dizygotic twins is likely to be an overestimation, whereas the correlation for the monozygotic twins is likely to be an underestimation.

Whereas memory accuracy, recollective experience, memory functionality, and the inhibition and mental flexibility processes of executive functioning did not yield twin pair resemblances that were not significantly different from 0, other aspects of memory were found to be moderately influenced by additive genetic or environmental factors. However, given the small sample size in the present study, these correlations should be interpreted with caution.

First, we observed similar correlations between the scores of monozygotic twins and dizygotic twins for the measure of memory specificity, suggesting that the specificity aspect of memory may primarily be influenced by environmental factors. This interpretation aligns with previous research that have found cultural differences in the specificity and detailedness of autobiographical memories (Humphries & Jobson, 2012; Wang et al., 2011). For instance, in a study by Wang and colleagues (2004), Euro-American, British, and Chinese participants were asked to recall as many childhood memories as they could in a 5-minute period. The authors reported that the Chinese sample provided fewer specific memories relative to their Euro-American and British counterparts. Similar results have also been observed during the retrieval of autobiographical memories in school-aged children. In a study by Han et al. (1998), Korean, Chinese, and Euro-American pre-school children were asked to retrieve a series of positive (e.g., one thing they did that was special or fun) and negative (e.g., when mom or dad scolded them) life events. Memories provided by the American children were found to be more vivid and contained more emotional details than memories retrieved by the Korean or Chinese children.

According to Wang (2009), these cultural differences may stem from factors such as the importance placed on emotions and parent-child reminiscing practices. In Western cultures, emotions are viewed as a direct expression of the self and “an affirmation of the uniqueness of the individual”. Parents in these cultures often prioritise raising children who are emotionally expressive, and importance is often placed on helping children understand and express their feelings (Gottman, 1998; Wang & Fivush, 2005). However, in many East Asian cultures, where emotions are thought to disrupt social harmony and need to be controlled, parents place less emphasis on emotional expression. Instead, they focus on raising children who behave in line with the standards set by society (Chen et al., 1998; Wang & Fivush, 2005). Although ample research has examined shared environmental factors (e.g., culture) that influence memory specificity, there are no studies that have looked at the influence of unique environmental factors on memory specificity. Future research should therefore aim to identify and examine the influence of unique environmental factors on memory specificity.

Furthermore, rumination was found to be highly heritable with an estimate of additive genetics of 0.862, and our finding was consistent with the literature on the genetic predispositions of rumination (Chen & Li, 2013; Johnson et al., 2014). For example, Moore and colleagues (2013) asked twins between the ages of 12 to 14 to complete the Response Style Questionnaire (which is a self-report measure of rumination) and found that rumination was moderately heritable. According to Johnson et al. (2016), rumination can often act as a mediator between the genetic predisposition of depression and the development and course of depression (also see Nolen-Hoeksema & Watkins, 2011). The authors suggest that people who are at a higher risk for depression would also be prone to experiencing rumination, which could then trigger the onset of depression. Although we did not measure the level of depressive symptoms among participants in the present study, future research could include measures of depression in the design to examine whether a large genetic overlap exists between rumination and depression. For example, Hilt and colleagues (2007) examined the relationship between rumination, depression, and the brain-derived neurotrophic factor (BDNF) Val66Met polymorphism gene. Women with adult-onset depression were classified into one of five genotype groups: Val/Val, Val/Met, Met/Met, Val, and Met. They then completed the Response Style Questionnaire (RSQ; Nolen-Hoeksema & Morrow, 1991) which measured rumination, and the Beck Depression Inventory – II (BDI; Beck et al., 1996), which measured depressive symptoms. The authors reported that rumination mediated the relationship between genotype and depressive symptoms, particularly in Val/Met heterozygotes.

The neural mechanisms of rumination found in previous studies further support the influence of additive genetics on rumination. The default mode network (DMN), which is a network of brain regions comprising the medial prefrontal cortex (mPFC), anterior cingulate cortex (ACC), and posterior cingulate cortex (PCC), is a network of brain regions that is crucial during autobiographical memory retrieval and self-referential thinking (Chou et al., 2023; Philippi et al., 2015; Qin & Northoff, 2011). People with depression exhibit higher activations in the DMN, especially in areas, such as the PCC and the dmPFC, during rumination compared to healthy controls (Cooney et al., 2010; Lemogne et al., 2009). Hamilton et al. (2011) further supported this notion by investigating the correlation between blood oxygenation level-dependent (BOLD) signatures in the DMN network (indicated by activations in the mPFC and the PCC) and the three subscales of the RRS (e.g., brooding, depression, and reflection). Whereas a positive correlation was found between the DMN network and depressive rumination, a negative correlation was found between the DMN network and reflective rumination.

Of the five executive functioning processes, only working memory capacity (a composite of visuospatial processing and forward and backward verbal learning) had a moderate estimate of additive genetics (A = 0.212), suggesting the heritability of working memory capacity. The results of our study are similar to those of Blokland et al. (2017) who showed that verbal learning and visuospatial learning both had heritability estimates of 0.520 and 0.500, respectively. Similarly, Tuulio-Henriksson and colleagues (2002) also showed that verbal working memory was moderately heritable and had an estimate of 0.420. The biological basis of working-memory capacity is also supported by studies examining the neural underpinnings of verbal learning and visuospatial processing. Hoshi and colleagues (2000), for instance, observed activations in the dorsolateral prefrontal cortex (DLPFC) when participants completed the Forward and Backward Digit Span tasks. Research on visuospatial process of working memory, on the other hand, found that damage to brain areas involving vision and spatial working memory is often associated with reduced performance in visuospatial tasks (Chechlacz et al., 2014). In their fMRI study, Chechlacz and colleagues (2014) used the Corsi-Block task with stroke patients to map the brain regions that are crucial for visuospatial processing. Lesions to areas, such as the occipital cortex and right posterior parietal cortex, led to poor performances during the task.

Because previous research has shown that working memory capacity and rumination are heritable (Johnson et al., 2014; Kremen et al., 2007), future studies could therefore carry out Genome-wide Association Studies (GWAS) to investigate the genetic underpinnings of memory by identifying genes that are associated to the rumination and working memory aspects of memory.

Apart from the influence of additive genetics, we also observed a moderate estimate of unique environmental factors (*E* = 0.555) for the aspect of working memory capacity. This finding is line with the literature suggesting that individual factors such as stress, sleep deprivation, and more could influence one's working memory capacity (de Wilde et al., 2015; Weerda et al., 2010). For example, in a meta-analysis by Lim and Dinges (2012), the authors found that an individual's working memory capacity can be greatly affected by even one night of sleep deprivation. Moreover, factors such as quality of schooling have also been found to influence the development of an individual's working memory capacity (de Wilde et al., 2010). In their longitudinal study, de Wilde and colleagues followed the development of the working memory capacity of preschool children over the course of 2 years. The authors reported that children who had warm relationships with their teachers tended to perform better on a visuospatial task compared to children who experienced conflict with their teachers. The authors also reported a negative association between teacher-child conflict and the development of working memory capacity.

Although the findings in the present chapter have provided valuable insights into the heritability of autobiographical memory, they are not without limitations. Given the small sample size and the exploratory nature of the present study, we felt that it was appropriate to use Falconer's method to estimate the heritability of the different aspects of memory. However, using Falconer's method with simple correlations can make it difficult to interpret estimates that do not make sense. For example, we found negative estimates for common environmental factors for the aspect of rumination (*C* = -0.418) and the mental flexibility (C = -0.062) process of executive functioning. Furthermore, we also found negative estimates of additive genetics for aspects such as memory accuracy (*A* = -0.238), and the inhibition (*A* = -

0.608) processes of executive functioning. Taken together, these results may reflect noise in the data rather than meaningful inverse relationships. That being said, future researchers should consider model-fitting approaches (comparing ACE and AE models) to obtain more reliable estimates.

Conclusions

In the present study, we attempted to examine whether the different components of autobiographical memory (i.e., accuracy, specificity, recollective experience, functionality, rumination, and executive functioning) are heritable. Of the six aspects, our factor analyses revealed one new factor: working memory capacity (which was a composite of visuospatial processing and forward and backward verbal learning). Overall, our findings suggest that rumination and the working memory capacity aspects of autobiographical memory were moderately heritable. We did not, however, find cross twin correlations between the remaining aspects of memory, possibly because the study was underpowered or because the measures that had been used were unreliable.

Chapter 4: Examining the Roles of Visual Imagery and Working Memory in the Retrieval of Autobiographical Memories using a Dual-Task Paradigm

Autobiographical memory is regarded as a memory system that encompasses a rich database of knowledge about oneself and is an essential component of the human experience (Brewer, 1996; Conway & Pleydell-Pearce, 2000; Rubin et al., 2003). According to Tulving (1972, 1983), autobiographical memory comprises both personal episodic information (i.e., unique information such as your wedding day) and personal semantic information (e.g., knowing where and when you were born).

The functions of autobiographical memories have been well documented (e.g., Bluck, 2003; Bluck & Alea, 2011). Bluck and colleagues (2005) suggested that the functions of autobiographical memory can be organised into three distinct categories: self, social, and directive. First, the self-function reflects memories' role in maintaining the sense of self over time (Baddeley, 1988; Habermas & Bluck, 2000). Second, the social function reflects memories' role in eliciting empathy and providing information for conversations during social bonding (Habermas & Bluck, 2000). Third, the directive function reflects memories' role in directing future behaviour through solving current problems and planning future actions (Pillemer, 2009). However, recent studies have suggested that autobiographical memories may have a fourth function which is emotion regulation, as their recollection has been reported to protect against mood disorders and depression (Öner & Gülgöz, 2018; Pillemer, 2009; Williams et al., 2015).

Whereas the previous two chapters had examined the mechanisms underlying autobiographical memory retrieval on a between-subjects level, the present chapter will go a level lower, and examine the cognitive mechanisms underlying autobiographical memory retrieval on a more within-subject level. Across two studies, we examined the contributions of visual imagery and working memory using a dual-task paradigm, as recent studies have shown that these components play an integral role in the recollection of autobiographical memories (e.g., Greenberg & Knowlton, 2014; van den Hout et al., 2012). While viewing a blank screen, following a dot on a screen, or viewing a screen with Dynamic Visual Noise (DVN; which is a visual interference task known to disrupt visual imagery processing; Quinn & McConnell, 1996), participants retrieved autobiographical memories.

Memory Retrieval

When examining memory retrieval, some individuals demonstrate an effortless ability to remember their past experiences. For instance, LePort and colleagues (2012) showed that some people can easily recall vivid events from any point in their lives (otherwise known as highly superior autobiographical memory). Other individuals, however, show a diminished ability to retrieve specific recollections (Palombo et al., 2015). When asked to retrieve specific memories, people with depression often retrieve more categoric memories (i.e., memories for repeated events) or extended memories (i.e., memories that last longer than a day) compared to healthy individuals (Liu et al., 2013; Sumner, 2012). The disparity between the types of recollections during retrieval suggests that autobiographical memories are stored in varying levels of specificity. According to the Self-Memory System model by Conway and Pleydell-Pearce (2000), autobiographical memories are organised hierarchically. The top of the hierarchy comprises overarching themes (e.g., education, family, work, relationships) and lifetime periods (e.g., primary school, secondary school, university). The intermediary level, however, consists of knowledge of general events, such as specific events (e.g., meeting X for the first time), temporally extended events (e.g., vacation), and repeated events (e.g., Christmas gatherings). The lowest level of the hierarchy stores event-specific knowledge (e.g., the place, the day, or the time of occurrence) and perceptual and sensorial details for those general events.

The retrieval of autobiographical memories was initially viewed as a single cyclical process that begins with cue elaboration, search for the memory, and verification until the memory sought after is found (Norman & Bobrow, 1979). More recent studies, however, have put forward a dual-process account of autobiographical memory retrieval: *direct retrieval* where memories are retrieved quickly and without apparent effort, and *generative* or *indirect retrieval*, where effortful search strategies are employed to search for the memory in the hierarchical structure (Conway, 2005; Conway & Pleydell-Pearce, 2000). More recently, Mace and colleagues (2017) have argued that the recollection of autobiographical memories may involve multiple retrieval strategies such as a *repeating strategy* (when cues are repeated internally until the memory sought after comes to mind), and a *temporal recall strategy* (where an individual uses temporal information, such as the day and time of the week, as cues during recall). The multiple-process account suggests that the strategies employed during memory retrieval are mainly driven by the circumstances (i.e., cue relevance, retrieval intentionality, or monitoring processes) in which the memory is retrieved (Barzykowski et al., 2019; Uzer & Brown, 2017).

The present studies focused on the retrieval of specific autobiographical memories (i.e., personal events that happened at a particular place and time; Williams & Broadbent, 1986). According to the Self-Memory System model, the retrieval of specific memories occurs via the dual-process approach: direct and generative processes (Conway, 2005; Conway & Pleydell-Pearce, 2000). Direct retrieval is an effortless process that is said to be spontaneously activated by environmental cues. In contrast, the generative retrieval of memories is an effortful process of memory construction, beginning at the top of the hierarchy which stores overarching themes and lifetime periods, moving through to general memories, and finally, to event-specific knowledge that is stored at the bottom of the hierarchy (Conway & Rubin, 1993). Across two studies, we examined two mechanisms involved in the retrieval of specific autobiographical memories: Working memory and visual imagery.

Working Memory and Autobiographical Memory

Working memory is regarded as a cognitive system with a limited capacity that holds information for short periods of time (Baddeley, 1992). Previous studies have shown that the retrieval of specific memories heavily relies on the control processes of working memory (Baddeley & Wilson, 1986; Conway, 1992; Daselaar et al., 2008). These control processes help establish contexts and are important for cue elaboration during the search for memories in the autobiographical knowledge base (Unsworth et al., 2012).

Support for the role of working memory during retrieval also stems from studies that have reported a strong association between working memory and the retrieval of autobiographical memories (e.g., Kemps & Tiggemann, 2007; Maxfield et al., 2008). For instance, higher levels of overgeneral memories (OGM) have been observed in individuals with difficulties in updating and maintaining information in the working memory and in individuals with a low working memory capacity (Ros et al., 2010; Yanes et al., 2008).

Previous studies have used a dual-task paradigm to investigate the relationship between working memory and autobiographical memories. Anderson and colleagues (2012) asked participants to retrieve autobiographical memories while completing a random number generator task which engaged working memory. Higher retrieval latencies and reduced specificity were observed for memories in the concurrent task condition than in the control condition. Similarly, Eade and colleagues (2006) reported similar observations when participants were required to retrieve specific memories while completing a random button-pressing task. Based on the aforementioned dual-task paradigms, it is plausible that when the working memory is occupied, the retrieval of specific autobiographical memories is impaired.

Andrade and colleagues (1997) proposed the working memory theory to explain why working memory taxations lead to fewer specific memories during recall. This theory suggests that, unlike long-term memory, working memory has a limited capacity to hold information. In a typical dual-task paradigm, working memory is taxed when both tasks compete for the limited working memory capacity. Due to the competition between the tasks, fewer attentional resources will be available to search for the memory in the hierarchical structure.

The benefits of working memory taxation can be observed in eye movement desensitization reprocessing (EMD-R) studies (van den Hout, Engelhard, Rijkeboer, et al., 2011). EMD-R is a psychotherapy that claims to alleviate the vividness and emotional distress brought about by the recollection of traumatic memories (El Haj et al., 2017; Gunter & Bodner, 2008). When an individual is required to recall their traumatic memories while making eye movements, both tasks compete for the limited resources of the working memory (Baddeley, 2007). The simultaneous execution of these dual-attention tasks could therefore impair the recollection of emotional memories, which may in turn, result in the retrieval of memories that are less emotional and less vivid (van den Hout & Engelhard, 2012).

Visual Imagery and Autobiographical Memory

Apart from working memory, visual imagery is also regarded by many researchers as one of the components involved in the recollection of specific autobiographical memories (Brewer, 1988, 1996; Brewer & Pani, 1996). Conway (1988) and Pillemer (1984) proposed that specific memories possess a strong sensory-perceptual component as they are often predominantly recalled in the form of visual images. Support for this notion stems from research reporting strong associations between visual imagery and autobiographical memory. First, Rubin and colleagues (2003) found that autobiographical memories with a strong sense of reliving are often accompanied by vivid visual images. Second, high imageability cues have been reported to lead to more specific memories with faster retrieval times than low imageability cues (Williams et al., 1999). Third, researchers have reported an enhanced recollection of autobiographical memories in individuals with a higher ability for mental imagery compared to individuals with a lower ability for mental imagery (Vannucci et al., 2016). Support for the role of visual imagery in the retrieval of specific memories also stems from neuropsychological studies. Greenberg and Rubin (2003) found a reduced ability to construct visual images during memory retrieval in patients with damage to the occipital lobe (which is involved in the processing of visual information).

Studies using dual-task paradigms have shown that the retrieval of specific memories is impaired when participants are required to retrieve memories while completing a secondary task (Anderson et al., 2012; Eade et al., 2006). To illustrate this impairment, Anderson and colleagues (2017) found that when participants attended to DVN that occupied the visual areas, the specificity of the memories retrieved was reduced. The researchers proposed that during generative retrieval, the participants were less efficient at distinguishing between specific and general memories in the hierarchical structure. Furthermore, the participants could not imagine the sensorial and perceptual details of the memory for direct retrieval, because their ability to mentally visualise such details was compromised. Similarly, Sheldon and colleagues (2019) also reported that the ability to form event-specific details was impaired when participants imagined autobiographical scenarios while viewing a DVN. They argued that visual imagery processing allows one to access and link specific episodic details while forming autobiographical representations. Based on the aforementioned findings, it is apparent that visual imagery also plays an important role in the retrieval of autobiographical memories.

Study 1

It is difficult to determine whether the higher retrieval latencies and reduced specificity of the memories during retrieval are due to interference in the visual imagery process or working memory. Therefore, the present study aims to examine the contribution of visual imagery and working memory during the retrieval of autobiographical memories. Akin to previous research, a dual-task paradigm was administered in the present study, and participants were required to retrieve specific memories while attending to a secondary task: following a moving dot, viewing DVN, or viewing a blank screen (control). The presentation of the DVN during retrieval is known to disrupt performance on visual imagery tasks which require the reconsolidation of information from memory, but not on working memory tasks that require the maintenance of visual information in the working memory (Andrade et al., 2002; Dean et al., 2005; Sheldon et al., 2017).

The taxation of the working memory, however, was achieved by asking participants to follow a moving dot on the screen during retrieval. Support for the moving-dot condition stems from EMD-R laboratory analogue studies that have reported that making horizontal eye movements during memory retrieval taxes the working memory (van Veen et al., 2016; van Veen et al., 2015). Participants were presented with a cue word. As soon as they had retrieved a specific memory that was somehow related to the cue word, they pressed a button. The time between the presentation of the cue word and the memory retrieval represents the retrieval latency. Participants then described the memory and rated the memory on several phenomenological characteristics, such as recollective experience and emotional intensity. The description of the memories was later scored on specificity.

Based on the literature, we developed two sets of hypotheses, one set focussing on retrieval time and one set focussing on memory phenomenology: (1) If only visual imagery plays a role in the retrieval of autobiographical memories, then memories retrieved in the DVN condition would be recalled slower than memories retrieved in the moving-dot and control conditions. On the other hand, if only working memory is involved in the retrieval of autobiographical memories, then memories retrieved in the moving-dot condition would be recalled slower than memories retrieved in the DVN and control conditions. However, if both visual imagery and working memory are found to contribute to the memory retrieval process, then memories retrieved in the moving-dot and DVN conditions would be recalled slower than memories retrieved in the control condition. (2) If only visual imagery plays a role in the retrieval of autobiographical memories, then memories retrieved in the DVN condition would be recalled with less recollective experience (and with reduced specificity and less emotion) than memories retrieved in the moving-dot and control conditions. However, if only working memory is involved in the retrieval of autobiographical memories, then memories retrieved in the moving-dot condition would be recalled with less recollective experience (and with reduced specificity and less emotion) than memories retrieved in the DVN and control conditions. If both visual imagery and working memory contribute to the memory retrieval process, then memories retrieved in the moving-dot and DVN conditions would be recalled with less recollective experience (and with reduced specificity and less emotion) compared to memories retrieved in the control condition.

In the present study, we tracked participants' gaze using a Desktop-mounted EyeLink 1000 plus while they viewed either a DVN, moving dot, or a blank screen. However, midway through the data collection process, we encountered an unexpected technical issue. Despite our best efforts to troubleshoot the issue, we were unable to find a quick fix and were forced to terminate the study early.

Method

Design

A within-subjects design with one factor was proposed. The independent variable was the experimental conditions during which autobiographical memories were retrieved: DVN, moving dot, and blank. The dependent variables were the retrieval latencies, and the characteristics of the memory retrieved (i.e., memory specificity, recollective experience, vantage perspective, emotional intensity, and emotional valence).

Participants

An a priori power analysis was conducted using the software MorePower 6.0 (Campbell & Thompson, 2012) to determine the number of participants required for a repeated measures ANOVA with three within-subject factors. However, given the large number of dependent measures and many missing values in the data, linear mixed models (LMM) and cumulative link mixed models (CLMM) were used in the analyses instead. The specified effect size was medium (f = .25), the alpha was set at .05, and the power at .80. The number of groups was 1, and the number of measurements was 3. The analysis indicated that a sample size of 94 would be sufficient to obtain sufficient statistical power. However, we aimed to recruit a total of 104 participants for the potential exclusion of outliers.

Because there were technical issues with the eye-tracking device used in the present study, we terminated data collection after testing 57 participants from the University of Nottingham Malaysia. The datasets of seven participants were removed from the analyses because the total gaze sample fell below 80% of the total trial time (i.e., lost track for more than 12 out of the 60 seconds of the total retrieval time per trial). Furthermore, we excluded four people from our analyses because they produced more than three omissions or semantic associations. As a consequence, the final sample consisted of 46 participants (31 females and 15 males) who were between 18 and 36 years old (*M* = 22.89, *SD* = 4.30). The present study was approved by the Science and Engineering Research Ethics Committee (SEREC) of the University of Nottingham Malaysia (KA201120).

Materials and Apparatus

The Dynamic Visual Noise (DVN). The DVN (see Figure 4.1) is known to interfere with visual imagery processing and consists of an array of squares that switch between the colours black and white at a rate of 52.5% per second (Anderson et al., 2017; McConnell & Quinn, 2004). Over the course of 1000 ms, about half of the black squares changed to white (and vice versa) to provide the appearance of change.

Figure 4.1

An example of the DVN that was presented during memory retrieval.

Stimuli. Table 4.1 shows 24 single-word cues obtained from previous studies that were used in the present study (Talarico et al., 2004; Williams et al., 1996). These cue words consisted of positive (both high and low arousal) and negative (both high and low arousal) cues. Although not part of the study design, a mix of positive and negative cue words were used as previous studies have shown differences in the temporal distribution and the phenomenological characteristics of memories from these categories. Collins and colleagues (2007), for instance, showed that positive cues tend to elicit memories that are more recent, whereas negative cues tend to elicit memories that are more evenly distributed across the lifespan. Furthermore, a recent meta-analysis by Preko et al. (2023) showed that positive cues tend to elicit memories that are more specific than negative cues. Given these differences, we believe that using cues from different valence groups would ensure a broader and more representative sample of autobiographical memories.

The emotional valence of the stimuli was validated through a pilot study where participants were required to rate the emotional valence of 36 cue words on a seven-point scale, ranging from 1 (‘very negative’) to 7 (‘very positive’). The pilot study took approximately five minutes to complete. A one-way ANOVA was conducted to determine whether the mean emotional valence of the 12 positive, 12 negative, and 12 neutral cue words differed, $F(2, 33) = 219.67$, $p < .001$, $\eta_p^2 = .930$. The analysis revealed that the valence of the positive words ($M = 6.02$, $SD = 0.34$) was significantly higher than the negative words ($M = 2.05$, $SD = 0.45$) and the neutral words ($M = 4.51$, $SD = 0.55$), and the negative words received significantly lower ratings of emotional valence than the neutral words, *p*s < .001.

A further 2 × 2 repeated-measures ANOVA was also conducted to determine whether the mean emotional valence and the mean emotional intensity of 24 cue words (four positive – high arousal, four positive – low arousal, four negative – high arousal, and four negative – low arousal) were different. The analysis showed a main effect of valence, $F(1, 11) = 627.67$, $p < .001$, $\eta^2 = .98$, and intensity, $F(1, 11) = 122.74$, $p < .001$, $\eta^2 = .92$. These results suggest that positive cue words elicited more positive emotions than negative cue words, and that high arousal cue words ($M = 3.29$, $SD = 0.20$) elicited more intense memories than low arousal cue words ($M = 2.80$, $SD = 0.39$). We also found an interaction effect between the intensity and the valence of the cue words, $F(1, 11) = 157.78$, $p < .001$, $\eta^2 = .94$. The interaction effect suggests that as arousal of the cue words becomes higher, the valence of positive cue words becomes higher but the valence of negative cue words becomes lower.

Table 4.1

The emotional valence, emotional intensity, and the mean valence ratings of the stimuli in the pilot study.

Valence	Intensity	Cue Words	Mean Valence Ratings	Mean Arousal Ratings
Negative	High Arousal	Anger	1.75 (.83)	3.25 (.83)
		Disgusted	1.70 (.56)	3.30 (.56)
		Sad	2.20 (.98)	2.90 (.77)
		Disappointed	1.50 (.50)	3.50 (.50)
		Ashamed	1.85 (.57)	3.15 (.57)
		Anxious	1.90 (.83)	3.10 (.83)
	Low Arousal	Bored	3.05 (.74)	2.05 (.59)
		Embarrassed	2.45 (1.28)	2.85 (.79)
		Annoyed	1.65 (.73)	3.35 (.73)
		Tired	2.50 (.50)	2.50 (.50)
		Fear	1.80 (.68)	3.20 (.68)
		Inferior	2.25 (1.18)	2.95 (.80)
Positive	High Arousal	Proud	5.80 (1.69)	3.25 (.94)
		Happy	6.40 (.58)	3.40 (.58)
		Excited	6.40 (.49)	3.40 (.49)
		Success	6.60 (.49)	3.60 (.49)
		Brave	6.05 (.97)	3.15 (.73)

	Love	6.30 (1.23)	3.50 (.74)
Low Arousal	Satisfied	6.15 (.85)	3.15 (.85)
	Surprised	5.55 (1.02)	2.55 (1.02)
	Calm	5.45 (.97)	2.55(.80)
	Amused	5.65 (.48)	2.65(.48)
	Relieved	5.65 (.73)	2.65(.73)
	Hope	6.25 (.83)	3.25 (.83)

Note. Standard deviations of the mean valence ratings are reported in parentheses.

Eye-tracking Apparatus. The experiment used a Desktop-mounted EyeLink 1000 plus (SR Research Ltd., Mississauga, Ontario Canada), a video-based eye-tracking device with a temporal resolution of 1,000 Hz and a spatial resolution of 0.01°. The eye tracker followed the participants' gaze position, and a 21-inch display PC (1920 x 1080 pixels) displayed the experiment via MATLAB (Version R2017a) and Psychtoolbox (Brainard, 1997; Pelli, 1997). Before data collection, a 9-point calibration procedure was performed, with successful calibration requiring <1° of error per point. To minimize head movements, participants used a chin rest, and the viewing distance was fixed at 65 cm.

Procedure

Before the experiment began, participants were provided with information about the study and asked to complete the consent form and to give demographic information (e.g., age and gender).

Participants were then given instructions and told that they would be presented with 12 positive or negative single-word cues (see Table 4.1). Upon cue presentation, they were instructed to retrieve a specific memory (relevant to the cue) for an event that they had personally experienced in the past. They were also told that the cues would only be presented briefly and would disappear quickly, and they were not to take their eyes off the screen during memory retrieval. Participants were further informed that they would need to attend to either a moving dot, a DVN, or a blank screen (i.e., control condition) during memory retrieval. They were told to fixate on either the moving dot or the DVN during retrieval, and a failure to do so would result in a continuous tone being heard. The continuous tone ensured that participants attended to the moving dot, the DVN, or the blank screen while retrieving the memory.

After retrieving the memory, participants were instructed to press the ‘spacebar’ key and subsequently to describe the memory. They were told to provide specific details of the memory (i.e., where and when the event occurred, what they were doing, who was present, what their feelings were). Lastly, they were informed that they would be provided with a practice trial with a neutral cue word before the beginning of each block of the experiment. Once the instructions were understood, the experiment began.

There were three blocks in the present experiment. Each block represented one condition and the order in which the blocks were presented was counterbalanced across participants to minimise order effects. Before beginning each block, participants completed a practice trial where they were presented with a fixation cross for 3000 ms at the centre of the screen. The fixation cross was then followed by a neutral cue word (e.g., garden, listening, book, city, fire, or flower) that was presented at the centre of the screen for 1000 ms. When the cue was presented, participants were given one minute (i.e., retrieval phase) to retrieve a specific autobiographical memory for a past personal event. Once a memory had been successfully retrieved, they pressed the ‘spacebar’ key to proceed to describe the memory. All the experimental trials followed the same parameters and timeline. After completing all trials in one block condition, the next block condition would be presented.

In the blank screen condition, participants were presented with a blank black screen during the retrieval phase. In the moving-dot condition, an additional task was administered during the retrieval process, where participants were required to attend to a horizontally moving dot that shifted from the left region to the right region of the monitor and back, at an amplitude of 11.36°. Furthermore, the radius of the dot was set at 0.1° and the speed of the dot was set at 0.83 Hz (number of left-right-left movements per second). Lastly, in the Dynamic Visual Noise condition, participants retrieved memories while attending the DVN stimulus. A continuous tone with a frequency of 1000 Hz was sounded to alert the participants if they looked away from the screen in the blank condition, if their gaze drifted 1° away from the centre of the dot in the moving dot-condition, or if their gaze drifted 6.45° away from the centre of the DVN. This tone ensured that participants maintained fixation on the blank, DVN, and moving-dot conditions during retrieval.

After participants finished describing the retrieved memory, they were also asked to rate the recollective experience for each memory (i.e., 'While remembering the memory, I felt as though I was reliving it') on a 7-point Likert scale ranging from 1 ('not at all') to 7 ('as if it were happening right now'). Several other memory characteristics (i.e., vantage perspective, emotional intensity, and the emotional valence of the memory) were also rated with similar 7-point Likert scales (see Table A3 in Appendix O).

Participants repeated this procedure of retrieving, describing, and rating an autobiographical memory four times. Once for a positive, high arousal cue word; once for a positive, low arousal cue word; once for a negative, high arousal cue word; and once for a negative, low arousal cue word. Each condition received one cue word from each category, so the emotional valence and emotional intensity of the cue words was equally distributed across the conditions. The order of these four kinds of cue words was randomised.

To minimise the number of missing values, if the participant did not recall a memory associated with the cue word presented from one category within one minute, they were presented with another cue word from that pool of six cue words. For instance, if a participant was presented with a negative high arousal cue word (e.g., anger) and was unable to recall a memory for this cue word, they were provided with a different negative high arousal cue word (e.g., disgusted). However, if they were still unable to recall a memory for the second cue word, the current trial was considered as an omission and they would proceed to the next trial, which could be either retrieving a memory associated with a cue word from a different category or progressing to the next block.

When the participants successfully retrieved and rated memories for all three blocks, the experiment ended. The experiment took about 45 to 60 minutes to complete. Participants were then given a debriefing sheet and thanked for their contribution. They also received course credit for their participation.

Coding

The memories retrieved were classified by two researchers into one of four categories based on their varying levels of specificity: specific (if the event occurred at a particular time or place, and lasted no longer than a day), categoric (if the memory is a repeated event), extended (if the event lasted longer than a day), and semantic associations (a direct verbal association of the cue word). If participants were unable to retrieve a memory, their response was considered as an omission. All the memories in this study were coded by two independent researchers, and the inter-rater reliability was computed using Cohen's Kappa. The agreement between the researchers was high, $k = .81$.

Subsequently, the individual memories were categorised into specific and non-specific memories. Whereas specific memories were given a score of 1, non-specific memories and omissions were given a score of 0. The specificity score for each participant was then calculated by summing the number of specific memories retrieved across the 12 cue words.

Results

Despite the early termination of data collection, the results of the present experiment are still valuable and worth exploring. Although the sample size is smaller than originally planned, the collected data can still provide important insights into the mechanisms underlying the retrieval of autobiographical memory.

We first examined the difference in the retrieval latencies and specificity of the memories between the blank, DVN, and moving-dot conditions by fitting three linear mixed models using the *lme4* package in R-Studio (Bates et al., 2015; RStudio Team, 2020). In these analyses, a fixed effect of conditions and a random effect of subjects were included. In the model that compared the proportion of non-specific memories (i.e., categoric, extended, or semantic associations) and omissions between the conditions, an additional fixed effect of memory errors (non-specific memories vs. omissions) was added. The significance of the main effects was tested using the *anova* package, and the estimated marginal means were computed using the package *emmeans* (Lenth, 2022). Tukey corrections were applied to account for family-wise errors.

Retrieval Latencies

To examine whether there were changes in the retrieval latencies across the blank, DVN, and moving-dot conditions, we performed a linear mixed effect model analysis. The analysis revealed a main effect of conditions, $F(2, 504) = 7.69$, $p < .001$, $\eta_p^2 = .030$. Our post-hoc analyses revealed that memories in the blank condition ($M = 11.63$ s, $SD = 8.11$ s) were recalled more quickly than memories in the DVN condition (*M* = 15.16 s, *SD* = 11.94 s), $t(504) = -3.85$, $p < .001$, $d = -.401$, and the moving-dot condition (*M* = 13.98 s, *SD* = 11.30 s), $t(504) = -2.57$, $p = .028$, $d = -.268$. There was no significant difference in the retrieval latencies between the DVN and moving-dot conditions, $t(504) = 1.28$, $p = .405$, $d = .134$.

Memory Specificity

When examining the number of specific memories retrieved across the different secondary tasks, we found no main effect of conditions, $F(2, 90) = 1.54$, $p = .219$, $\eta_p^2 = .030$. A LMM was also fitted to determine whether there were differences in non-specific responses or omissions across the different conditions. The mixed model analysis revealed a main effect of memory errors, $F(1, 225) = 88.93$, $p < .001$, $\eta_p^2 = .028$. There was no main effect of conditions, $F(2, 225) = 1.03$, $p = .359$, $\eta_p^2 = .009$, and no interaction effect between the different conditions and memory errors, $F(2, 225) = 0.84$, $p = .431$, $\eta_p^2 = .007$. Overall, although participants may have produced more non-specific responses (*M* = 25.54, *SD* = 27.60) than omissions (*M* = 3.62, *SD* = 9.81), there was no difference in the type of error produced across the three conditions. The means and standard deviations for the different types of memories retrieved are included in Table 4.2.

Table 4.2

The means (and standard deviations) of the proportions of specific memories, non-specific memories, and omissions across the different conditions for Study 1.

	Proportion of memories or omissions recalled		
Type of memory	Blank	DVN	Moving dot
Specific	.685 (.286)	.685 (.318)	.755 (.244)

Non-Specific	.261 (.258)	.288 (.316)	.217 (.251)
Omissions	.054 (.117)	.027 (.095)	.027 (.079)

Memory Characteristics

We also fitted a series of cumulative link mixed (CLM) models using the *ordinal* package in R-Studio (Christensen, 2019) to determine whether there were changes in memory characteristics (i.e., recollective experience, vantage perspective, emotional intensity, and emotional valence) across the different conditions (see Table 4.3).

Recollective Experience. To determine whether there was a difference in the levels of recollective experience across the different conditions, we fitted a CLM model to the data. In this model, a Chi-Squared (χ^2) test revealed that there was no main effect of conditions, $\chi^2(2) = 1.369$, $p = .504$. Participants experienced similar levels of reliving across the blank, DVN, and moving-dot conditions.

Vantage Perspective. Like recollective experience, we compared the ratings of field perspective for the memories retrieved across the blank, DVN, and moving-dot conditions, and found that there was no main effect of conditions, $\chi^2(2) = 0.425$, $p = .808$. Similar results were also found for the observer perspective model. There was no significant difference between the ratings of observer perspective across the three secondary tasks, $\chi^2(2) = 0.158$, $p = .924$.

Emotional Intensity and Valence. The CLM model revealed no significant difference between the emotionality of the memories in the blank, DVN, and moving-dot conditions, $\chi^2(2) = 0.868$, $p = .648$. Finally, we also fitted a CLM model to determine whether there were changes in the emotional valence of the memories across the blank, DVN, and moving-dot conditions. The emotional valence of the memories did not differ between the different conditions, $\chi^2(2) = 3.13$, $p = .208$.

Table 4.3

The means (and standard deviations) of the different memory characteristics as a function of their conditions.

	Conditions		
Memory Characteristics	Blank	DVN	Moving dot
Recollective Experience	5.30 (1.30)	5.22 (1.27)	5.21 (1.35)
Field Perspective	5.02 (1.74)	4.88 (1.80)	4.98 (1.76)
Observer Perspective	3.50 (2.14)	3.56 (2.05)	3.55 (2.08)
Emotional Valence	4.51 (1.89)	4.16 (1.93)	4.27 (1.90)
Emotional Intensity	4.85 (1.57)	4.80 (1.49)	4.73 (1.64)

Discussion

In the present study, we aimed to compare the roles of visual imagery and working memory during the retrieval of autobiographical memories in a dual-task paradigm. When examining the retrieval latencies between the blank, DVN, and moving-dot conditions, participants retrieved their memories more quickly in the blank condition compared to the DVN condition. This finding is line with the literature suggesting that visual imagery is important to the memory retrieval process (Anderson et al., 2012; Williams et al., 1999). When the DVN interfered with the visual imagery process during retrieval, it is possible that participants were less efficient at searching for the sensorial and perceptual details surrounding their memory in the autobiographical knowledge base. In addition, our results also revealed higher retrieval latencies in the moving-dot condition compared to the blank condition, and this finding is in line with the literature (Andrade et al., 1997). The working memory theory is a component that stores information for a short duration due to its limited resources. When participants in the present study were required to follow the moving dot and retrieve a specific memory at the same time, the resources in the working memory depleted. Therefore, participants needed some additional time to search for their memories in the autobiographical knowledge base.

Where the specificity of the memories is concerned, we found that the proportion of specific memories did not differ between the blank and the DVN conditions and this could be due to the fact that the study was underpowered (n = 46; observed power = 104). There was also no difference in the number of specific memories between the blank and the moving-dot conditions. Our findings contradict the notion that taxations to the working memory reduce the specificity of memories during retrieval (Eade et al., 2006), and this could be due to the difficulty of the task administered. We noticed that our participants often skipped the presentation of the moving dot before even retrieving a memory because they had difficulties following the moving dot. After skipping the presentation of the memory, participants may have had some additional time to think about the details of their memory on the page where they described their memory. This procedural artifact likely inflated specificity in the moving-dot condition.

As for the remaining memory characteristics, there were no significant differences in the ratings of recollective experience, vantage perspective, emotional intensity, and emotional valence across the different secondary tasks, and our findings are partially in line with the literature. Anderson and colleagues (2017) proposed that the DVN merely delays memory retrieval but does not reduce the phenomenological quality of the memories retrieved. This may explain why we found no difference in any of the memory characteristics between the blank and DVN conditions.

However, the notion that making horizontal eye movements reduces the emotionality of the memories retrieved was not supported (van den Hout, Engelhard, & Rijkeboer, 2011). The emotional intensity and the emotional valence of the memories retrieved did not change between the moving-dot and the blank condition. The *U-curve hypothesis* by Gunter and Bodner (2008), suggests that taxing the working memory too little or too much will yield little or no effect (see General Discussion for a more detailed discussion of this hypothesis). The moving-dot condition administered in the present study may have been too taxing on participants' working memory and may have led to a lack of reductions in the levels of emotionality between the memories in the moving-dot and blank condition.

Study 2

We administered a dual-task paradigm similar to Study 1 but with a few modifications. First, because there were technical issues with the EyeLink 1000 Plus system, we used the EyeLink Portable Duo system to track participants' gaze position. Like the EyeLink 1000 Plus, the EyeLink Portable Duo has a temporal resolution of 1,000 Hz and a spatial resolution of 0.01°. Second, it is possible that some of the null results from Study 1 may be due to the difficulty of the moving-dot task. To address this concern, the parameters of the moving-dot condition (i.e., the radius, amplitude, and speed of the dot) were modified to make the task slightly easier (see Procedure section for more details). Third, we also included an additional dependent variable of vividness to examine whether the vividness of the memories changed across the blank, DVN, and moving-dot conditions. Fourth, we included a one-point drift correction procedure at the beginning of each trial to reduce potential noise brought about by drifts in participants' gaze. Fifth, for the dependent variables of emotional intensity and emotional valence, we included an additional independent variable when we compared emotions at the time of the experience to emotions at the time of the recollection because it has been shown that negative memories lose their intensity faster than positive memories (Walker et al., 1997; Walker et al., 2003). Finally, we added a skip logic between the presentation of the stimuli and the retrieval phase to allow participants to skip words for which they had no memory.

The hypotheses of the present study were akin to Study 1: (1) If only visual imagery plays a role in memory retrieval, then memories retrieved in the DVN condition would be recalled slower than memories retrieved in the moving-dot and control conditions. Conversely, if only working memory is involved in the retrieval of autobiographical memories, then memories retrieved in the moving-dot condition would be recalled slower than memories retrieved in the DVN and control conditions. However, if both visual imagery and working memory are found to contribute to the memory retrieval process, then memories retrieved in the moving-dot and DVN conditions would be recalled slower than memories retrieved in the control condition. (2) If only visual imagery plays a role in the retrieval of autobiographical memories, then memories retrieved in the DVN condition would be recalled with less recollective experience (and with reduced specificity and less emotion) than memories retrieved in the moving-dot and control conditions. However, if only working memory is involved in the retrieval of autobiographical memories, then memories retrieved in the moving-dot condition would be recalled with less recollective experience (and with reduced specificity and less emotion) than memories retrieved in the DVN and control conditions. If both visual imagery and working memory contribute to the memory retrieval process, then memories retrieved in the moving-dot and DVN conditions would be recalled with less recollective experience (and with reduced specificity and less emotion) compared to memories retrieved in the control condition.

Method

Design

Again, a within-subjects design with one factor was implemented. The independent variable was the experimental conditions during which autobiographical memories were retrieved, and the dependent variables were the retrieval latencies and the characteristics of the memory retrieved (i.e., memory specificity, recollective experience, vividness, vantage perspective, emotional intensity, and emotional valence). For the dependent variables of emotional intensity and emotional valence, there was an additional independent variable when we compared emotions at the time of the experience to emotions at the time of the recollection.

Participants

Similar to Study 1, a power analysis was conducted to determine the number of participants required for a one-way repeated-measures ANOVA with three factors (Faul et al., 2007). However, we decided to conduct a series of linear mixed models (LMM) and cumulative link mixed models (CLMM) instead due to the large number of dependent measures and many missing values in the data. Although the analysis indicated that a sample size of 94 would be sufficient to obtain sufficient statistical power, we tested 116 students from the University of Nottingham Malaysia to account for the exclusion of outliers. Because the total gaze sample of six participants fell below 80% of the total trial time (i.e., lost track for more than 12 out of the 60 seconds of total retrieval time), their datasets were removed from the analyses. Second, the dataset of one participant was also removed because the computer on which the study was presented crashed during the completion of the experiment. Third, if participants failed to recall a memory or if the mean reaction time between indicating that they retrieved the memory and describing the memory was greater than 2 standard deviations above the mean reaction time for each participant (~5.11 seconds), their response would be considered as an omission. Finally, fourteen participants were removed from the analyses because they produced more than three omissions or semantic associations during retrieval. The final sample consisted of 72 female and 23 male participants, who were between 16 and 34 years old (M = 20.00, SD = 2.43). The present study was approved by the Science and Engineering Research Ethics Committee (SEREC) of the University of Nottingham Malaysia (KA201120).

Materials and Procedure

The present study used the same stimuli and applied the same procedure as Study 1, but there were a few changes. Instead of using the EyeLink 1000 Plus to track participants' gaze, the present experiment was conducted using a EyeLink Portable Duo (SR Research Ltd., Mississauga, Ontario Canada), a video-based eye-tracking device with a temporal resolution of 1,000 Hz and a spatial resolution of 0.01°. Furthermore, the parameters of the moving dot were also modified to be less stringent. The amplitude and the radius of the moving dot was increased from 11.36° to 16° and from 0.1° to 0.5°, respectively. The speed of the moving dot was also reduced from 0.83 Hz to 0.67 Hz (number of left-right cycles per second).

Next, we added a skip logic between the presentation of the stimuli and the retrieval phase to allow participants to skip words for which they had no memory. During the memory retrieval phase, when participants had successfully retrieved a memory, they pressed the 'spacebar' key to proceed, and were prompted to indicate if they had successfully retrieved a memory or not using a binary number to indicate 'yes' or 'no'. Indicating 'yes', would subsequently prompt them to describe the retrieved memory, whereas indicating 'no' would lead to a new cue word being presented. In addition to the skip logic, we also added a one-point drift correction procedure at the beginning of each trial to reduce potential noise brought about by drifts in participants' gaze.

Once a memory had successfully been retrieved, participants rated the recollective experience and vantage perspective for each memory. They were also required to rate the vividness of the memory (i.e., 'How vivid was the memory that you had just recalled?') on a 7-point Likert scale ranging from 1 ('not vivid') to 7 ('very vivid'). Participants were also asked to rate the emotional intensity of the memory at experience (and at recollection), and the emotional valence of the memory at experience (and at recollection) on similar 7-point Likert scales.

Coding

All the memories in the present study were coded by two independent researchers, and the inter-rater reliability was computed using Cohen's Kappa. The agreement between the researchers was high, $k = .94$. Disagreements between the researchers were resolved through discussion. Similar to Study 1, the memories retrieved were first classified into one of four categories based on their varying levels of specificity: specific (if the event occurred at a particular time or place, and lasted no longer than a day), categoric (if the memory is a repeated event), extended (if the event lasted longer than a day), and semantic associations (a direct verbal association of the cue word). If participants were unable to retrieve a memory or took longer than expected (~5.11 seconds) between indicating that they had retrieved a memory and describing the memory, their response was considered as an omission.

Similar to Study 1, the memories were then categorised into specific and non-specific memories. Whereas specific memories were given a score of 1, non-specific memories and omissions were given a score of 0. The specificity score for each participant was then calculated by summing the number of specific memories retrieved across the 12 cue words.

Results

Retrieval Latencies

To examine the changes in retrieval latencies across the blank, DVN, and moving-dot conditions, we performed a linear mixed effect model analysis. The analysis revealed a main effect of conditions, $F(2, 947.21) = 6.82$, $p < .001$, $\eta_p^2 = .001$. Pairwise comparisons showed that participants recalled their memories more quickly in the blank condition ($M = 16.63$ s, $SD = 13.48$ s), compared to the DVN condition ($M = 18.98$ s, $SD = 13.40$ s), $t(946) = -3.07$, $p = .006$, $d = -.232$, and the moving-dot condition ($M = 19.06$ s, $SD = 13.20$), $t(947) = -3.30$, $p = .002$, $d = -.253$. There was no significant difference in the retrieval latencies between the DVN and moving-dot conditions, $t(948) = -0.28$, $p = .960$, $d = -.021$.

Memory Specificity

In the model that compared the number of specific memories recalled while participants attended to the different secondary tasks, we found no main effect of conditions, $F(2, 188) = 2.85$, $p = .061$, $\eta_p^2 = .015$. Similar to the results of Study 1, we observed no reductions in memory specificity when participants attended to the different secondary tasks.

To determine whether there were more non-specific responses or omissions across the different conditions, we again fitted a linear mixed effect model. Although there was no main effect of conditions, $F(2, 470) = 1.85$, $p = .159$, $\eta_p^2 = .006$, a main effect of memory errors was found, $F(1,470) = 56.54$, $p < .001$, $\eta_p^2 = .088$. There was also no interaction effect between the different conditions and memory errors, $F(2, 470) = 0.79$, $p = .453$, $\eta_p^2 = .003$. Overall, these results suggest that although participants produced more non-specific responses ($M = 20.88$, $SD = 23.23$) than omissions ($M = 8.69$, $SD = 15.46$), there was no difference in the type of error produced across the three conditions. The means and standard deviations for the different types of memories retrieved are included in Table 4.4.

Table 4.4

The means (and standard deviations) of the proportions of specific memories, non-specific memories, and omissions across the different conditions.

	Proportion of memories or omissions recalled		
Type of memory	Blank	DVN	Moving dot
Specific	.705 (.247)	.742 (.238)	.666 (.267)
Non-Specific	.221 (.236)	.190 (.230)	.216 (.232)
Omissions	.074 (.136)	.068 (.123)	.118 (.192)

Memory Characteristics

We also fitted a series of cumulative link mixed (CLM) models using the *ordinal* package in R (Christensen, 2019) to determine whether there were changes in the characteristics of the memories retrieved (i.e., vividness, recollective experience, vantage perspective, emotional intensity, and emotional valence) across the different conditions (see Table 4.5). In the two models that explored the emotionality of the memories, an additional fixed effect of time (at experience vs. at recollection) was added.

Vividness. In the CLM model that compared the ratings of vividness for memories retrieved across the different secondary tasks, we included the variables conditions as the fixed effect and subjects as the random effect. A Chi-square (χ^2) test revealed that the ratings of vividness did not change when participants attended to the different secondary tasks, $\chi^2(2) = 2.54$, $p = .281$.

Recollective Experience. Apart from ratings of vividness, we also performed a CLM model analysis to compare the levels of recollective experiences for memories retrieved across the different conditions. This analysis showed a main effect of conditions $\chi^2(2) = 10.45$, $p = .005$. Participants experienced the strongest sense of reliving for memories retrieved in the DVN condition compared to the memories retrieved in the moving-dot condition, $z = -50.48$, $p < .001$, OR = .647, and the blank condition, $z = -35.03$, $p < .001$, OR = .739. They also experienced a stronger sense of reliving in the moving-dot condition than in the blank condition, $z = -10.93$, $p < .001$, OR = 1.142.

Vantage Perspective. We also fitted a CLM model to compare the ratings of field perspective for the memories retrieved across the blank, DVN, and moving-dot conditions. In this model, no main effect of conditions was found, $\chi^2(2) = 5.50$, $p = .064$. Our findings revealed no differences in the ratings of field perspective when participants attended to the different secondary tasks. For the observer perspective model, we similarly found that there was no difference between the blank, DVN, and moving-dot conditions, $\chi^2(2) = 0.84$, $p = .657$. Following this analysis, we conducted a Wilcoxon signed-ranks test to determine whether there was an overall difference in the ratings of field and observer perspective across all participants. The analysis revealed that participants tended to retrieve their memories more from a field perspective ($M = 5.08$, $SD = 1.71$) than from an observer perspective ($M = 3.27$, $SD = 1.97$), $Z = -16.56$, $p < .001$.

Emotional Intensity. For the emotional intensity CLM model, we included a fixed effect of time in this model to compare the emotional intensity of the memories at two timepoints; at the time the event was experienced and at the time the event was remembered.

Although we did not find a main effect of conditions, $\chi^2(2) = 2.63$, $p = .269$, we found a main effect of time, $\chi^2(1) = 88.26$, $p < .001$. There was no interaction between the retrieval conditions and time, $\chi^2(2) = 0.23$, $p = .892$. Although there was no interaction effect, participants often reported that they had felt stronger emotions at the time the event was experienced ($M = 5.36$, $SD = 1.57$) than at the time the event was remembered ($M = 4.79$, $SD = 1.67$).

Emotional Valence. Like emotional intensity, we also investigated whether there was a change in the emotional valence of the memories between the two timepoints across the blank, DVN, and moving-dot conditions. In this CLM model, we found no main effect of conditions, $\chi^2(2) = 1.30$, $p = .522$. This model also revealed that the emotional valence of the memories did not change between the time when the event was experienced and the time when the event was remembered, $\chi^2(1) = 2.72$, $p = .099$. We also found no interaction effect between conditions and time, $\chi^2(2) = 0.214$, $p = .899$. A comparison of the retrieval latencies, memory specificity, and the phenomenological properties of the memories retrieved between Studies 1 and 2 is illustrated in Figures A10 – A12.

Table 4.5

The means (and standard deviations) of the different memory characteristics as a function of their conditions.

	Conditions		
Memory Characteristics	Blank	DVN	Moving dot
Vividness	5.47 (1.48)	5.59 (1.42)	5.52 (1.46)
Recollective Experience	4.90 (1.53)	5.19 (1.49)	5.13 (1.41)

Field Perspective	5.01 (1.72)	5.21 (1.74)	5.03 (1.66)
Observer Perspective	3.33 (1.99)	3.24 (1.97)	3.25 (1.95)
Intensity at Experience	5.33 (1.55)	5.41 (1.57)	5.34 (1.59)
Intensity at Recall	4.70 (1.70)	4.85 (1.64)	4.82 (1.67)
Valence at Experience	3.88 (2.12)	3.88 (2.15)	4.01 (2.08)
Valence at Recall	4.02 (1.76)	4.03 (1.88)	4.10 (1.84)

Discussion

When examining the roles of visual imagery and working memory during retrieval, our results demonstrate that people recalled their memories more slowly when they attended to either the DVN or moving dot during retrieval, suggesting that visual imagery and working memory both contribute to the memory retrieval process (Williams et al., 1999; Baddeley, 1992).

In terms of memory specificity, we found no difference in the proportion of specific memories between the blank and DVN conditions. Because the cues in the present studies were all low imageability cues, participants may not have had to rely much on visual imagery processes to visualize a specific memory in their minds. Therefore, the effects of the DVN may have been too small for an effect to be observed. Moreover, the proportion of specific memories also did not differ between the blank and moving-dot conditions. Our results counter the finding that taxations to the working memory leads to reductions in memory specificity during retrieval (Anderson et al., 2012; Eade et al., 2006), and this lack of reductions could be due to methodological differences. For instance, in the study by

Anderson et al. (2012), participants continued to attend to the secondary task (i.e., random number generator) while describing their memory to the researchers. In the present study, the moving dot was only presented during the memory retrieval phase. When participants successfully retrieved a memory, the secondary task was terminated. Because the moving dot was absent when the event was being described, participants may have had some additional time to think about other details surrounding their memory, possibly undermining the effects of the task. Future research can therefore implement a paradigm in which participants are required to describe their memories in verbatim while continuing to follow the moving dot. Retrieval latency would be calculated from the time that the cue word is presented to the time that the participant starts describing the personal event.

Apart from the proportion of specific memories, we also found that participants in the present study recalled more non-specific responses (20.9%) than omissions (8.7%) across the different conditions. Because there was no interaction between the memory errors and the conditions, the extent to which the secondary tasks interfered with the hierarchical search for specific memories is unclear.

Although we expected the levels of reliving to be lower in the DVN and moving-dot conditions, our findings were quite the opposite. Participants experienced higher levels of reliving in the DVN and moving-dot conditions compared to the blank condition. Our findings can be explained by the *threshold hypothesis* (see General Discussion). Our results also showed that the emotional intensity and emotional valence of the memories did not differ between the different tasks. When we further compared the emotional intensity of the memories between the time of experience and the time of recollection, we only found a main effect of time. Participants reported that they had experienced stronger emotions at the time the event was experienced than when it was recalled, and this finding was in line with the

Fading Effect Bias (Walker et al., 1997), which suggests that both positive and negative emotions associated with autobiographical memories fade over time.

Numerous studies have shown an interplay between recollective experience, emotional intensity, and vantage perspective (Janssen et al., 2022; Libby & Eibach, 2011; Phelps & Sharot, 2008; Sutin & Robins, 2010). Therefore, we explored whether there was a difference in the vantage perspective from which the memories were recalled across the DVN, moving-dot, and control conditions. The analyses were purely exploratory as no specific predictions were made. Our findings suggest that the ratings of both the field and observer perspectives did not change across the three conditions.

Although there were no significant differences, we observed a trend in the memories as the overall ratings for memories retrieved from the field perspective were higher than the overall ratings for memories retrieved from the observer perspective. When retrieving autobiographical memories, people tend to recall recent memories, such as events that have transpired in the last five years, compared to memories from the earlier part of their lives (Rubin & Wenzel, 1996; Sederberg et al., 2008). Memories for recent events, in turn, tend to be recalled from a field perspective than an observer perspective (Nigro & Neisser, 1983; Rice & Rubin, 2009; Robinson & Swanson, 1993). Therefore, participants' preference for recalling more recent events may explain why memories in Study 2 were mostly recalled from a field perspective. Because there was no objective measure to assess the recency of the memories retrieved in the current design, future studies can modify the design of the Study 2 to include judgments of temporal distance between encoding and retrieval for each of the memory retrieved or include instructions to retrieve memories from certain lifetime periods.

General Discussion

In the present studies, we compared the relative contributions of visual imagery and working memory during the retrieval of autobiographical memories. To make this comparison, we asked participants to retrieve specific memories while following a moving dot, viewing DVN, or viewing a blank screen. When we compared the retrieval latencies between the different conditions across both studies, we found that memories in the DVN and moving-dot conditions were recalled slower than the memories in the blank condition, but no differences in the retrieval latencies between the DVN and moving-dot conditions. These findings are in line with the literature suggesting that an increase in cognitive load in the moving-dot condition (van Veen et al., 2015) as well as a limitation in the ability to construct mental representations in the DVN condition (Anderson et al., 2017) led participants to experience difficulties in retrieving event-specific information from the autobiographical knowledge base.

When examining the specificity of the memories between the conditions across both studies, we found no difference in the proportion of specific memories recalled between the blank and DVN conditions. Although Anderson et al. (2017) reported that viewing DVN led to reductions in memory specificity, it is important to consider that the authors had asked participants to retrieve memories for both high and low imageability cues. Because high imageability cues often invoke memories that are richer in contextual and peripheral details (Rasmussen & Berntsen, 2014; Williams et al., 1999), the role of visual imagery processing may be stronger for high imageability cues compared to low imageability cues. When participants were required to attend to a DVN during retrieval in Anderson et al.'s study, the ability to construct vivid mental representations was compromised, and this in turn, led to reductions in memory specificity in the DVN condition. We may not have observed similar results in our studies because our cues were all low imageability cues (e.g., anxious, tired, excited, amused). Because participants retrieved their memories in response to low imageability cues, they did not rely much on visual imagery processes to generate a specific mental image in their mind. The interference caused by the DVN may therefore be weak and could have led to a lack of difference in the proportion of specific memories between the blank and the DVN conditions.

In terms of the characteristics of the memories retrieved, there was no difference in the ratings of vividness and emotionality of the memories between the DVN and the blank conditions across both studies. Similar to the study by Anderson and colleagues (2017), the current study found that the DVN only interferes with the memory retrieval process but does not degrade the phenomenological qualities of the retrieved memories. Although we did not find evidence for floor or ceiling effects, the lack of differences could also be attributed to the fact that the ability to retrieve and reconstruct autobiographical memories varied across participants (Sheldon et al., 2017). If the sample in both studies would have been comprised of participants who tend to have vivid memories, then the DVN might have interfered with the retrieval process, but if the sample would have consisted of participants who do not tend to have vivid memories, then the DVN might not have interfered. By measuring one's imagery ability before the experiment (with, for example, the Autobiographical Recollection Test, Berntsen et al., 2019), future researchers would be able to confirm the effects of the DVN for participants with different imagery abilities.

Whereas many studies have shown that taxing the working memory reduces the phenomenological quality of the memories retrieved (Kavanagh et al., 2001; Leer et al., 2014; van den Hout et al., 2001; van Veen et al., 2015), the present studies found no difference in the levels of vividness and emotionality between the memories in the moving-dot and blank condition. Our null findings align with previous research suggesting that working memory taxation does not affect the vividness and the emotionality of the memories retrieved (van den Hout, Engelhard, Beetsma, et al., 2011). The discrepancy between the findings of these dual task paradigms may be explained by the inverted *U-curve hypothesis* by Gunter and Bodner (2008). The hypothesis suggests that when the working memory is weakly taxed during retrieval, enough resources would still be available to retrieve vivid and emotional details surrounding an event and the effects of the task would be undermined. Conversely, when the working memory is taxed too much, all available resources are depleted, and this depletion leaves very little room for recall. In other words, taxing the working memory too little or too much will yield little or no effect. Although the parameters of the moving dot condition were adjusted to be less stringent in Study 2, it is possible that the moving-dot condition administered was still too taxing on participants' working memory. Because the moving-dot condition depleted all the resources in the working memory during retrieval in both Studies 1 and 2, there were no reductions in the levels of vividness and emotionality between the memories in the moving-dot and blank condition.

When examining whether there was a difference in the levels of reliving across the three conditions, we expected to find reductions in ratings of recollective experience for memories retrieved in the DVN and moving-dot conditions. In Study 1, we found no difference in the levels of reliving across the different tasks, and this absence could be due to the fact that the experiment was underpowered. The results of Study 2, on the other hand, indicated that participants experienced a stronger sense of reliving in the DVN and moving-dot conditions compared to the control condition. This unexpected increase in levels of reliving may be explained by the *threshold hypothesis,* which suggests that all memories need to pass an awareness threshold to be remembered (Barzykowski & Staugaard, 2016, 2018). These authors suggested that highly accessible memories, such as emotional or recent memories, are often remembered without apparent effort because they pass the awareness threshold easily. Less accessible memories, on the other hand, have difficulties in passing said threshold. In Study 2, it is plausible that participants' memories that were accompanied by strong feelings of recollective experience in the DVN and moving-dot conditions could have passed the threshold. In addition, they might have directed more effort to the retrieval process in the control condition, allowing memories with both stronger and weaker feelings of recollective experience to pass the threshold, resulting in a lower average for recollective experience in the control condition. Although it is unclear why this explanation would apply to recollective experience but not emotional intensity or vividness, our present findings warrant serious consideration for the awareness threshold account than it has so far been given in the literature.

Although the findings from Studies 1 and 2 have yielded valuable insights into the memory retrieval process, they are not without limitations. For instance, although the moving dot condition was expected to tax working memory (without affecting visual imagery), it is possible that voluntary eye movements made during this task may have partially disrupted visual imagery processes. This notion is supported by studies that have shown that voluntary eye movements disrupt the spatial component of visual imagery (de Vito et al., 2014). Recent studies have also shown that gaze patterns observed during the encoding of scenes also seemed to match those observed during retrieval (known as gaze reinstatement), and that stronger gaze reinstatement is associated with higher memory accuracy (Wynn et al., 2019). To address this methodological limitation, future researchers could ask participants to retrieve specific memories in response to auditory cues as opposed to visual cues. We believe that employing an auditory task would allow future researchers to make a clearer distinction between the contributions of visual imagery and working memory during retrieval.

Conclusions

In the present study, we compared the roles of visual imagery and working memory during the retrieval of autobiographical memories. Across two experiments, we asked participants to retrieve their autobiographical memories while viewing a blank screen, viewing a DVN, or following a moving dot. We then compared the retrieval latencies, memory specificity, vividness, recollective experience, vantage perspective, and emotionality across the three conditions. Inhibiting visual imagery during retrieval merely delayed the retrieval process but did not affect the quality of the retrieved memories. The effects of the working memory taxation only resulted in longer retrieval latencies, and were not observed for the remaining memory characteristics, possibly because the task administered in the present studies may have been too difficult or because our studies were underpowered. The findings obtained across both studies suggest that both visual imagery and working memory play a role during the retrieval of autobiographical memory, but more research needs to be conducted to determine their exact roles.

Chapter 5: General Discussion

Summary of Main Findings

For decades, memory researchers around the world have sought to uncover the mechanisms underlying autobiographical memory retrieval. As a result of years of research, several models have been proposed, each offering insights into the cognitive, clinical, and biological mechanisms of memory retrieval. One of the most influential frameworks in this area is the Self-Memory System (SMS) model which suggests that autobiographical memories are stored in a hierarchical structure where themes and lifetime periods are stored at the top level, general events are stored at the intermediary level, and event-specific information are stored at the lowest level (Conway & Pleydell-Pearce, 2000; Conway, 2005). From a more clinical perspective, the CaR-FA-X model, which was built on the SMS model, was developed to explain why people with depression or PTSD have often difficulties retrieving specific autobiographical memories (Williams, 2006; Williams et al., 2007; Sumner, 2012). In addition to the cognitive and clinical models, Rubin (2005, 2006) introduced a biological model of memory retrieval known as the Basic-Systems Approach (BSA). This model suggests that autobiographical memories are formed by several lower-level systems with distinct neural substrates. Deficits in one or more of these systems is therefore said to reduce the phenomenological quality of the memory retrieved.

Although these theoretical models have provided valuable insights into the memory retrieval process, the researchers who proposed them examined these dimensions separately. For instance, whereas the SMS model and the Basic-Systems Approach have laid more emphasis on aspects, such as memory specificity, recollective experience, self-referential processing, emotion, and more, the CaR-FA-X model focuses more on dimensions, such as rumination and executive functioning. Therefore, it remains unclear whether these different dimensions of memory are related or whether they function independently. To bridge this gap in the literature, Chapter 2 of the present thesis examined whether aspects of autobiographical memory, such as memory specificity, memory accuracy, recollective experience, rumination, memory functionality, and executive functioning, are related. Across Studies 1 and 2 of Chapter 2, participants completed the Autobiographical Memory Test (AMT) which measured memory specificity and recollective experience, a 20-item recognition task which measured memory accuracy, the Ruminative Response Scale (RRS) which measured rumination, the Thinking About Life Experiences Scale (TALE) which measured memory functionality, and five executive functioning tasks which measured the mental flexibility, visuospatial learning, inhibition, and forward and backward verbal learning processes of executive functioning.

Findings from Chapter 2 revealed that people with higher brooding and reflection tendencies also tended to report higher levels of depressive symptoms. Furthermore, we also found that people who used their memories to guide their present and future actions were also more likely to use their memories to establish and maintain social relationships and maintain their sense of selves over time. When examining the associations between five executive functioning processes, only visuospatial processing and forward verbal learning were found to be related. In terms of the associations across the six aspects of autobiographical memory, we found that memory functionality was related to both recollective experience and rumination, respectively. Memory accuracy, memory specificity, and executive functioning, on the other hand, appeared to function independently.

Because the Basic-Systems Approach offers some support for the biological basis of autobiographical memory (Rubin, 2005, 2006), the third chapter of this thesis examined whether and to what extent the six aspects of autobiographical memory are influenced by additive genetics and environmental factors. Results from this chapter revealed that rumination and working memory capacity were heritable. The lack of correlations between the remaining aspects could be due to the study being underpowered or the measures used being unreliable.

Whereas Chapters 2 and 3 examined between-subject differences during memory retrieval, Chapter 4 of the present thesis goes a level lower, and examines within-subject differences observed during retrieval. For instance, some researchers examining memory retrieval argue that visual imagery plays a fundamental role (Anderson et al., 2017; Rubin et al., 2003). Other researchers, however, have argued that working memory is an integral component involved in memory retrieval (Anderson et al., 2012; Eade et al., 2006). To resolve these conflicting arguments, Chapter 4 compared the roles of visual imagery and working memory during the retrieval of autobiographical memories in a dual-task paradigm. In Study 1 of Chapter 4, participants recalled their memories while following a moving dot, viewing a DVN, or viewing a blank screen. The memories retrieved were then rated on different memory characteristics, such as recollective experience, vantage perspective, emotional intensity, and emotional valence. A similar procedure was administered in Study 2, but there were a few changes. The parameters of the moving-dot condition were modified to be less stringent. Apart from the memory characteristics included in Study 1, participants were also asked to rate the vividness and the emotional intensity (and valence) of their memories at two different timepoints (at experience vs. at recollection). Overall, results from both studies suggest that inhibiting visual imagery by having participants view DVN merely delayed memory retrieval but did not affect the phenomenological quality of the memories retrieved. Taxations to the working memory by having participants follow a moving dot only resulted in longer retrieval latencies, and no reductions in the specificity, vividness or the emotional intensity of the memories retrieved.

Theoretical Implications

The findings of this thesis have several theoretical implications. The CaR-FA-X model posits that high levels of rumination and impaired executive functioning often lead to reduced autobiographical memory specificity during retrieval (Williams et al., 2007). Because the present thesis found no correlations between memory specificity, rumination, and executive functioning, it is possible that that rumination and impaired executive control may not affect memory specificity as strongly in non-clinical samples as they would in people with depression, challenging the generalizability of the CaR-FA-X model. Partial support for the findings of the present thesis stems from a study by Ros and colleagues (2017) who examined the relevance of the CaR-FA-X model in a non-clinical sample of young and old adults. The authors reported that, across both age groups, there were no correlations between rumination and memory specificity. A positive correlation was only found between memory specificity and executive functioning. Additionally, in the older adult group, the authors reported a negative association between functional avoidance and memory specificity. In other words, individuals who exhibited higher functional avoidance strategies retrieved more specific memories.

Similarly, Fisk and colleagues (2019) also showed that the CaR-FA-X model (with the exception of the functional avoidance component) could only explain overgeneral memories in people with high depressive traits. They found that adolescents with higher depression scores ruminated more frequently, retrieved fewer specific memories, and had lower scores on executive functioning tasks that measured verbal working memory compared to those with lower depressive symptoms. Taken together with the findings of the present thesis, it is possible that reduced memory specificity, resulting from rumination, functional avoidance, and poor executive functioning, is an effect that is more prominent in clinical samples.

The heritability of rumination and working memory capacity found in the present thesis also has important implications for the Basic-Systems Approach (Rubin, 2005, 2006). As previously discussed, the Basic-Systems Approach suggests that autobiographical memory is formed by the interaction of several lower-level systems, such as attention, vision, and emotion. These basic systems have their own functions, their own processes, and their own neural substrates. Although factors, like genetics, were not considered in the original Basic-Systems Approach, the heritability of rumination and working memory capacity implies that the development of neural substrates related to some of the basic systems may be partially governed by genetic factors. The lack of support for genetic factors for the remaining aspects of memory (e.g., memory accuracy, recollective experience, memory functionality, and the mental flexibility and inhibition processes of executive functioning) does not mean that the theory is false. It is more likely that the present study used unreliable measures and was underpowered for these aspects (see the Discussion section of Chapter 3).

Furthermore, there was also an interesting pattern of results that was observed across the first two experimental chapters. In Chapter 2 of the present thesis, the relationship between visuospatial processing and verbal learning was no longer significant once a Bonferroni correction was applied. However, this relationship emerged once again in Chapter 3 when forward verbal learning, backward verbal learning, and visuospatial processing loaded onto a single factor called working memory capacity. It is possible that the alpha criterion applied in Chapter 2 was overly strict, and that a weak association between visuospatial processing and verbal learning exists. However, it is important to note that the correlations observed between forward verbal learning, backward verbal learning, and visuospatial processing in Chapter 2 were weak, suggesting that although these processes may share working memory resources, they also represent distinct processes of executive functioning. Future research could be conducted to better understand the true extent of the relationship between visuospatial processing and verbal learning.

Besides Chapters 2 and 3, findings from Chapter 4 have refined our understanding on the role of visual imagery during memory retrieval. Although there is evidence to suggest that the DVN interferes with the processing of visual information in the visual buffer of short-term memory (Quinn & McConnell, 2006), our studies revealed that the DVN is a stimulus that does not halt or abort the search for sensorial and perceptual details in the hierarchical base; instead, it delays the process. In other words, participants may take longer to retrieve their memories while viewing the DVN compared to when viewing a blank screen. However, the phenomenological characteristics of the memories will still be preserved (also see Anderson et al., 2017).

In terms of the role of working memory during retrieval, both our studies revealed that participants took longer to retrieve their memories in the moving-dot condition compared to the control condition. These results support the working memory theory which suggests that, unlike long-term memory, working memory is a component that has a limited capacity (Baddeley, 1992), and the simultaneous execution of the memory retrieval and following the moving dot taxed the limited capacity of the working memory, which resulted in the longer retrieval latencies. Although the working memory theory explains why there were delays in the retrieval process, the effects of the working memory on the remaining memory characteristics (e.g., vividness, vantage perspective, emotionality, etc.) were unclear.

Legal Implications

The findings from this thesis also carry important implications for eyewitness testimonies. For instance, studies have shown that witnesses who provide a detailed account of a crime are not necessarily more accurate in identifying the perpetrator (Wells & Leippe, 1981). Wells and Leippe (1981), for instance, examined the relationship between memory detailedness and accuracy of eyewitness identification. In their study, participants were seated in a room and were required to fill in a form with their demographic information. The experimenter then left the room to presumably get some materials for the experiment. Participants were then visited by a thief (an actor) who stole a calculator from the room they were in. Upon witnessing the crime, participants were required to pick a culprit from a lineup and were asked about the details surrounding the crime (e.g., the characteristics of the room they were in). The author showed that people who reported more details surrounding the crime also showed poorer accuracy for the identification of the perpetrator, suggesting that memory detailedness was not a strong predictor of accuracy. Taken together with the findings of Chapter 2, these results suggest a dissociation between memory accuracy and memory specificity. With this in mind, expert witnesses should educate judges, juries, and the general public that although a testimony from an eyewitness may appear to be vivid and compelling, it does not necessarily mean that it is accurate.

Clinical Implications

Besides legal implications, the present thesis has clinical implications too. Because rumination was found to be heritable and is a known mediator between the genetic predisposition and the development of depression (Johnson et al., 2016), individuals with high ruminative abilities and a family history of depression should be informed about their risk of developing depression. Following this notification, clinical experts should offer counselling and explain how genes may interact with environmental factors to contribute to the development of depression.

In addition to awareness, early interventions can be offered. Because rumination is formed through repetitive negative thinking styles (Watkins & Robert, 2020), frequent ruminators can be encouraged to attend rumination-focused cognitive behavioural therapy (RF-CBT), an intervention designed to reduce ruminative tendencies (Watkins, 2015; Watkins & Nolen-Hoeksema, 2014). Rooted in traditional cognitive behavioural therapy (CBT) techniques, RF-CBT features several novel elements. These elements include conducting a functional analysis to identify internal and external rumination triggers, controlled exposure to external stressors, and a focus on shifting from repetitive negative thinking to a more positive form of thinking. This shift in thinking is slowly adopted through a series of visualization, experiential exercises, or behavioural experiments.

The effectiveness of RF-CBT has been demonstrated in previous studies (Hvenegaard et al., 2019; Oei & Dingle, 2008). For example, in a study by Watkins and colleagues (2011), 42 patients were randomly assigned either to the treatment as usual condition (TAU), where patients were given antidepressants and attended outpatient clinical sessions, or the TAU+RF-CBT condition, where patients were additionally required to attend 12 sessions of RF-CBT. Compared to patients in the TAU condition, patients in the TAU+RF-CBT condition showed reduced levels of depression and rumination after 12 sessions. In a similar study, Jacobs and colleagues (2016) reported that adolescents with a history of MDD who received RF-CBT exhibited lower levels of rumination and depressive symptoms compared to the control group.

Mindfulness-based Cognitive Therapy (MBCT; Segal et al., 2002) which integrates mindfulness practices with CBT techniques, is another intervention that has been shown to effectively reduce rumination in people with depression (Jain et al., 2007; Michalak et al., 2011). A typical MBCT program is delivered over the course of 8 weeks, with each session lasting approximately 2 hours. During these sessions, participants are encouraged to focus on their present feelings and thoughts in a non-judgemental way. By promoting a mindful approach to one's internal experiences, the MBCT aims to disrupt the cycle of negative thinking about one's past, present, and future, and fosters self-compassion (Sipe & Eisendarth, 2012; Watkins & Roberts, 2020). For example, in a study by van Aalderen and colleagues (2012), patients with recurrent depression who received MBCT in combination with TAU reported significantly lower levels of depression and rumination compared to patients who underwent the TAU alone (also see Teasdale et al., 2000).

Early intervention programs in schools and universities can also be developed to mitigate rumination in students (Nolen-Hoeksema et al., 2007). Education institutions could promote physical exercise, which has been reported to reduce feelings of rumination (Brand et al., 2018). Furthermore, teaching people to be mindful of their thoughts and emotions can also help prevent the development of negative thinking patterns which can lead to depression. For instance, Lavadera and colleagues (2020) found that mindfulness in combination with aerobic exercise reduced ruminative tendencies in medical students. Over an 8-week period, participants engaged in two sessions of mental and physical trainings per week. Each session began with a 30-minute meditation session followed by a 30-minute session of aerobic exercise. Students who had completed 14 out of the 16 sessions reported fewer symptoms of brooding and depressive rumination at post-test compared to pre-test.

Methodological Implications

The findings of this thesis also carry important methodological implications for the field of autobiographical memory. Across both the studies in Chapter 2, most of the self-reported measures did not correlate with the behavioural tasks. Whereas self-reported measures, such as recollective experience, memory functionality, and rumination, often tap into the emotions and perceived experiences in one's life, behavioural tasks, like the executive functioning tasks, measure one's cognitive abilities (Sharma et al., 2014; Toplak et al., 2013). The prior measurements are subjective, whereas the latter measures are more objective. The difference in the constructs measured by the different tasks in our studies may therefore explain why we found correlations between the different self-report measures and between the different executive functioning tasks, but not between the self-report measures and the executive functioning tasks.

Although self-reported measures, such as the RRS and TALE, are known to reliable (Maki et al., 2015; Parola et al., 2017), and behavioural tasks, like the Flanker task, are known to produce robust within-subjects effects (Taylor & Ivanoff, 2005), the difference in constructs measured may limit their ability to measure stable individual differences. Bridging the gap between these constructs would therefore contribute toward our overall understanding of autobiographical memory retrieval. That being said, future researchers should develop measures which combine the strengths of self-report measures and behavioural tasks as these tools would aid future researchers in developing a better understanding of individual differences that exist during memory retrieval.

A Multidisciplinary Approach to Autobiographical Memory

The present thesis is the first in the field to integrate the biological, cognitive, evolutionary, forensic, and clinical perspectives of autobiographical memory. As mentioned previously, most of the findings from this thesis revealed that not all aspects of autobiographical memory are related, suggesting a huge disconnect between the different perspectives. Although the lack of associations between the different aspects could be due to several methodological limitations, the findings of the present thesis highlight the need to approach autobiographical memory research more holistically. When developing models of memory retrieval, future researchers should not only consider the cognitive mechanisms, but also the biological, evolutionary, and clinical frameworks of memory retrieval. By combining the findings from these different perspectives, future researchers would be able to develop a better understanding of the mechanisms underlying memory retrieval.

Limitations and Future Directions

The present thesis, like the ever-growing body of psychological research, is not without limitations. As previously discussed, although much of the literature surrounding the CaR-FA-X model suggests that rumination, functional avoidance, and impaired executive functioning are mechanisms that contribute to the retrieval of overgeneral memories (Williams et al., 2007; Raes et al., 2010; Sumner, 2012), the model may not necessarily apply to non-clinical populations. Because there are no studies that directly compare the mechanisms of the CaR-FA-X model between clinical and non-clinical samples, future researchers can administer the design of Chapter 2 to samples of clinically depressed and healthy individuals. By doing so, they would be able to better understand the role of the CaR-FA-X model across these different populations.

Another limitation observed in the second chapter of the present thesis is that the correlations between the five different processes of executive functioning (i.e., mental flexibility, visuospatial processing, inhibition, and forward and backward verbal learning) were either not significant or were weak to moderate in strength. Although all five processes are conceptualized to measure the underlying mechanisms of executive functioning, these tasks may assess different subcomponents of executive functioning that may not be related to each other (de Bruin, Bak, & Della Salla, 2015). Therefore, future studies should investigate the underlying mechanisms of executive functioning and identify specific mechanisms that are involved in the different tasks. By doing so, future researchers would be able to take a theory-driven approach when investigating the associations between autobiographical memory and the different executive functioning processes.

In addition, the lack of correlations between aspects, such as memory specificity and recollective experience, could be due to the limited number of trials used to measure each aspect. For example, across Chapters 2 and 3, memory specificity was assessed by asking participants to retrieve specific memories in response to only ten single-word cues. Recollective experience, on the other hand, was measured by asking participants to rate their feelings of reliving for these ten memories. Future studies should consider modifying the design of the study by incorporating a larger number of trials measuring memory specificity and recollective experience. They could also go a step further to analyse the narrative content of the memories provided to determine whether a thematic overlap exists between the memories provided by monozygotic twins and dizygotic twins.

Finally, although the findings from Chapter 4 have provided valuable insights into role of working memory during memory retrieval, we believe that the lack of differences in the phenomenological properties of the memories retrieved across the blank, moving-dot, and DVN conditions may have been due to the fact that the task administered (i.e., the moving-dot condition) was too difficult. According to the *U-curve hypothesis* (see General Discussion section of Chapter 4) by Gunter and Bodner (2008), taxing the working memory too little or too much would yield little to no effect. Because the moving-dot condition in both studies were too difficult, it may have used up all the resources in the working memory. Not enough resources were therefore available for memory retrieval, and this lack, in turn, may have resulted in small effect sizes. Future studies should therefore recruit a larger sample than Study 2 of Chapter 2 to examine whether small differences between the conditions can be observed for each memory characteristic.

Conclusions

The aim of the present thesis, albeit ambitious, was to bring together the biological, cognitive, evolutionary, forensic, and clinical perspectives of autobiographical memory. When examining whether the different aspects of autobiographical memory were related, memory functionality was found to be related to rumination and recollective experience, respectively. The remaining aspects of memory, such as memory accuracy, memory specificity, and executive functioning, seemed to be independent. Of the six components, only rumination and working memory capacity (which is a measure combining visuospatial processing and forward and backward verbal learning) were heritable. On a more within-subject level, the roles of visual imagery and working memory (mechanisms which are thought to underlie autobiographical memory retrieval) were further examined. Our findings revealed that interfering with visual imagery processing only delayed memory retrieval, but did not affect the phenomenological properties of the memories retrieved. In terms of the contribution of working memory to the memory retrieval process, the findings from this thesis were less clear. Our results showed that occupying the working memory only delayed memory retrieval and did not affect the remaining properties of autobiographical memory.

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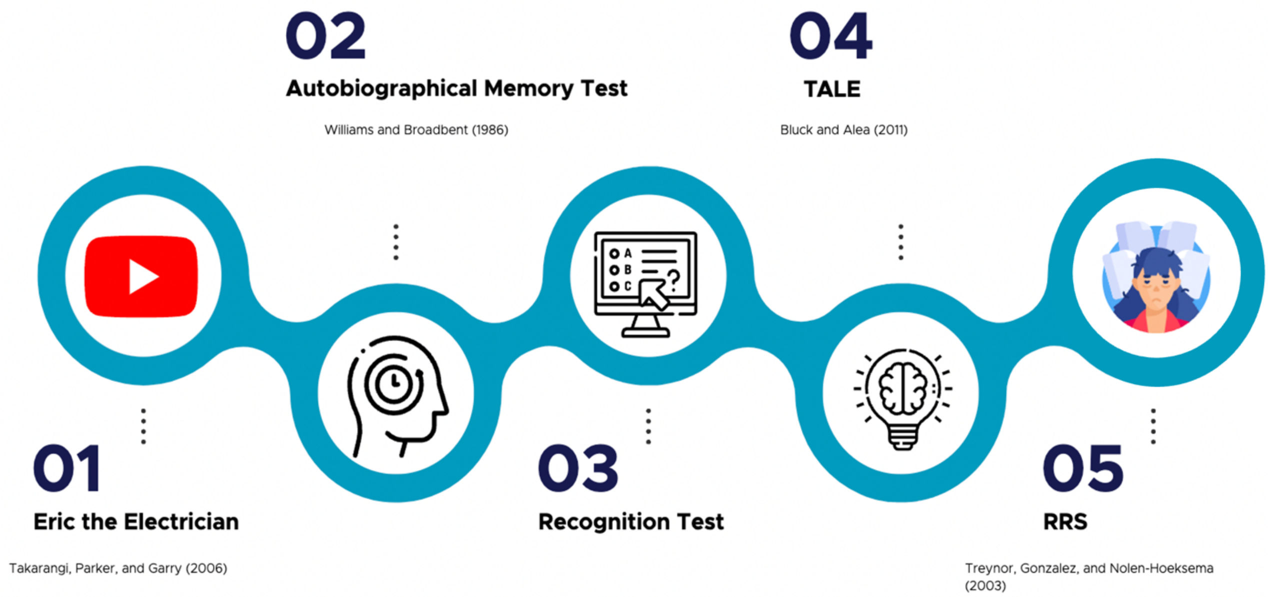
Appendix A

Figure A1

A figure of the tasks administered on Qualtrics



Appendix B

Table A1

The Bayesian Factor (BF_{01}) values for the different aspects of autobiographical memory

			Executive Functioning Tasks					RRS			TALE		
	Recollective experience	Memory accuracy	Inhibition	Mental Flexibility	Visuospatial Learning	Verbal learning – Forward	Verbal Learning – Backward	Brooding	Depression-related	Reflection	Social	Directing-behaviour	Self-continuity
Memory specificity	8.189	2.682	10.814	0.709	10.691	10.727	7.932	10.774	4.463	2.328	10.753	7.458	3.957
Recollective experience	--	6.808	2.755	9.283	10.352	10.452	8.640	1.254	0.181	2.150	0.145	0.813	0.322
Memory accuracy		--	10.377	7.638	8.592	10.480	6.385	4.168	10.108	9.905	10.622	3.302	10.827
Inhibition			--	3.592	10.151	6.192	6.164	8.723	10.412	9.978	5.852	9.732	8.153
Mental Flexibility				--	2.892	5.333	5.591	7.255	7.338	9.271	10.660	5.844	9.218
Visuospatial Learning					--	0.015	2.004	10.770	10.722	0.546	5.568	8.887	1.424

Verbal learning – Forward	--	< 0.001	7.247	9.620	9.657	6.550	8.141	2.249
Verbal Learning – Backward		--	8.952	5.787	9.592	1.787	10.825	1.762
Brooding			--	< 0.001	< 0.001	0.009	0.120	0.015
Depression-Related				--	< 0.001	0.009	0.669	.< 0.001
Reflection					--	2.201	0.501	0.002
Social						--	< 0.001	0.001
Directing-behaviour							--	< 0.001
Self-continuity								--

Appendix C

Table A2

The Bayesian Factor (BF_{01}) values for the different aspects of autobiographical memory

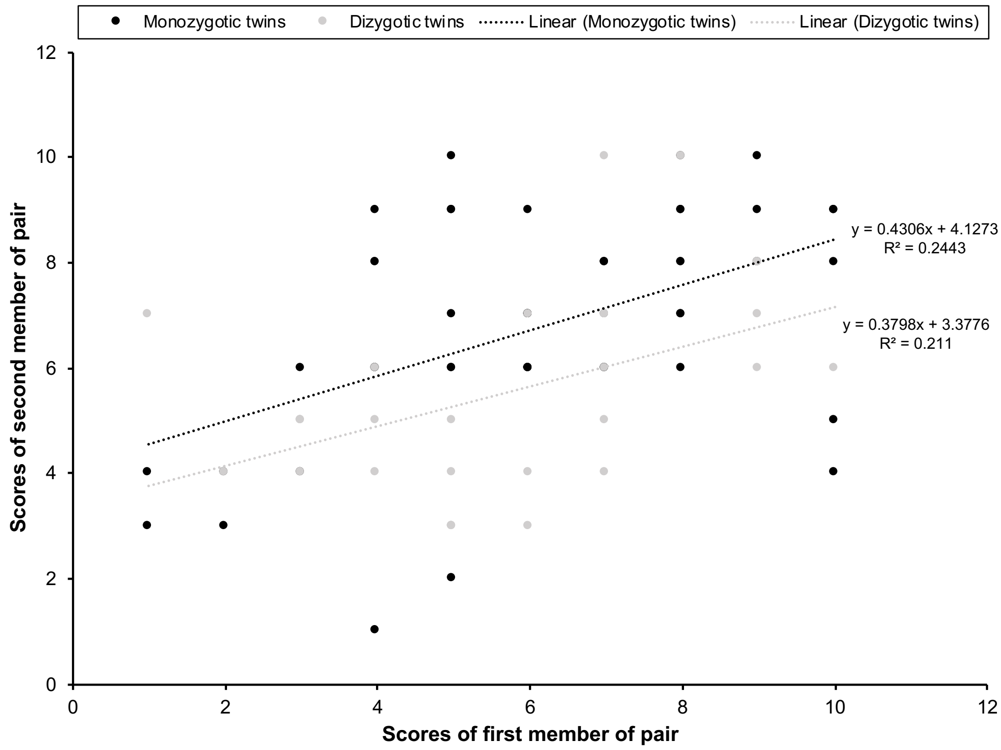
	Executive Functioning Tasks							RRS			TALE		
	Recollective experience	Memory accuracy	Inhibition	Mental Flexibility	Visuospatial Learning	Verbal learning – Forward	Verbal Learning – Backward	Brooding	Depression-related	Reflection	Social	Directing-behaviour	Self-continuity
Memory specificity	9.210	8.882	8.934	1.762	9.737	6.631	7.520	4.857	8.977	7.521	4.858	8.181	8.717
Recollective experience	--	4.707	9.564	6.259	9.186	8.075	6.665	3.984	5.909	5.642	3.136	0.019	1.263
Memory accuracy		--	9.882	6.570	6.767	2.264	3.403	9.858	9.622	9.361	0.928	9.845	9.964
Inhibition			--	9.609	9.576	1.178	7.067	5.668	1.226	6.817	8.902	6.148	7.659
Mental Flexibility				--	3.326	1.973	5.530	2.352	6.749	3.348	1.867	7.612	6.947
Visuospatial Learning					--	0.103	0.415	6.906	8.306	7.412	9.020	6.241	9.504

Verbal learning – Forward	--	< 0.001	6.924	7.064	8.615	1.767	9.838	8.665
Verbal Learning – Backward		--	5.886	7.392	6.738	5.895	9.531	9.859
Brooding			--	< 0.001	< 0.001	0.131	1.135	< 0.001
Depression-Related				--	< 0.001	0.325	1.862	.< 0.001
Reflection					--	0.079	0.001	< 0.001
Social						--	< 0.001	0.163
Directing-behaviour							--	< 0.001
Self-continuity								--

Appendix D

Figure A2

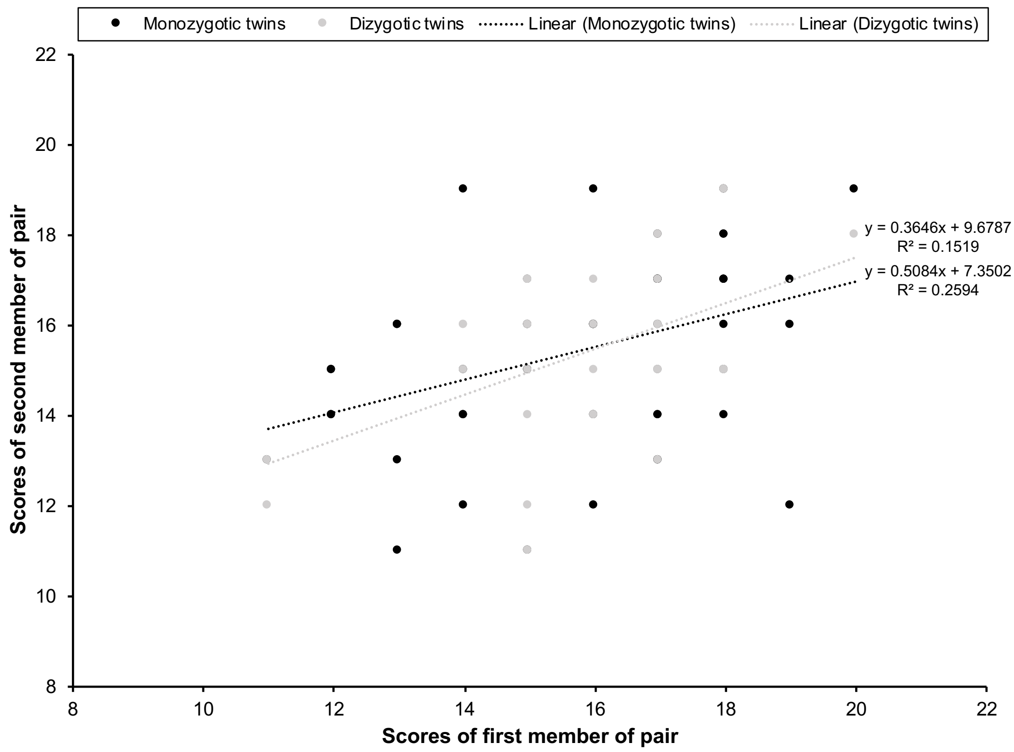
A scatter plot of the scores obtained by both zygosity groups for the specificity aspect of memory



Appendix E

Figure A3

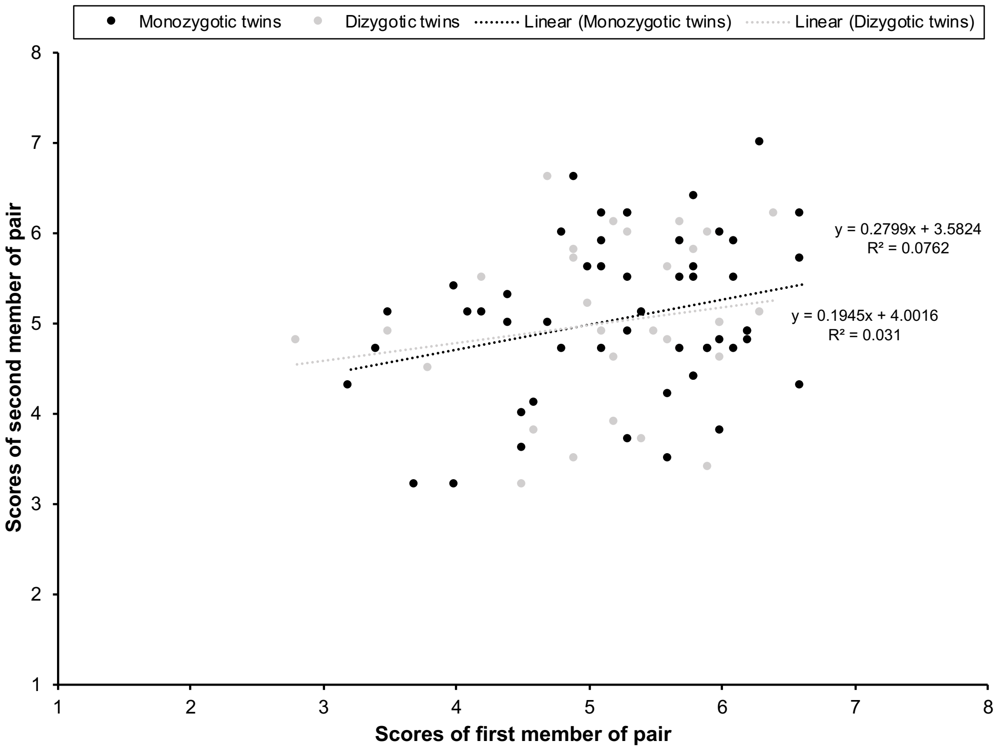
A scatter plot of the scores obtained by both zygosity groups for the accuracy aspect of memory



Appendix F

Figure A4

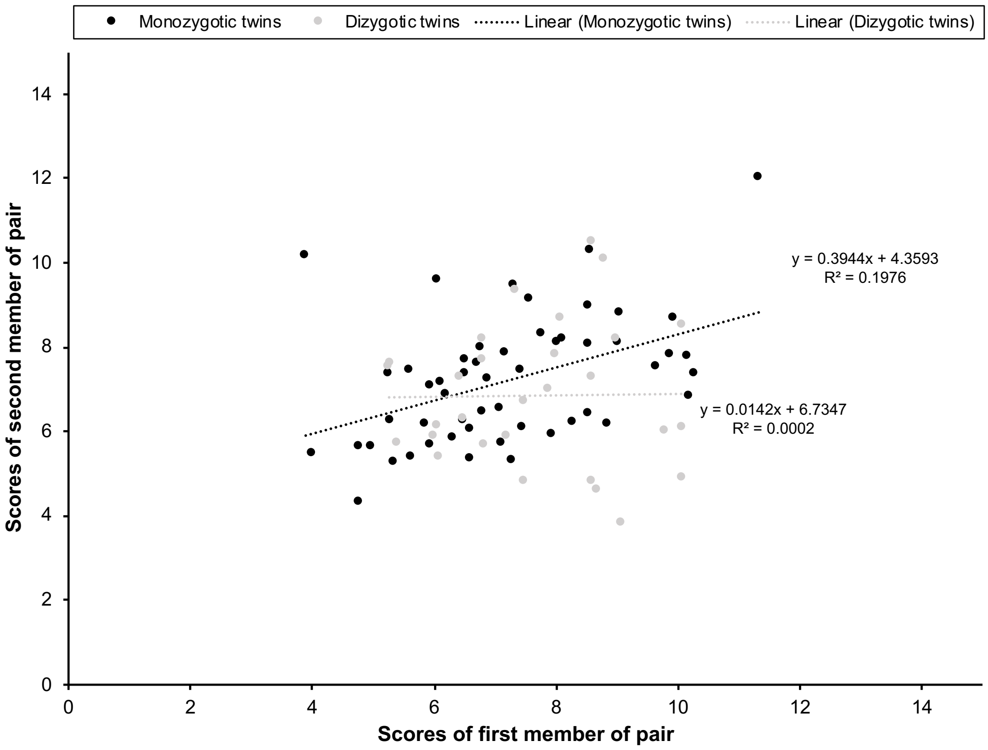
A scatter plot of the scores obtained by both zygosity groups for the recollective experience aspect of memory



Appendix G

Figure A5

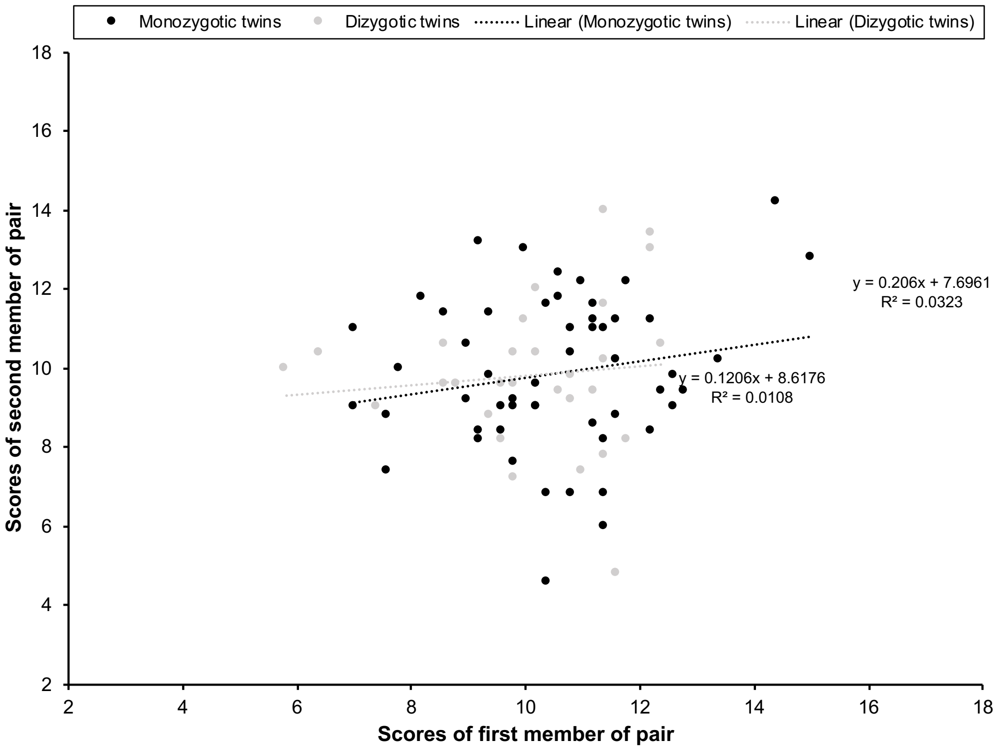
A scatter plot of the scores obtained by both zygosity groups for the rumination aspect of memory



Appendix H

Figure A6

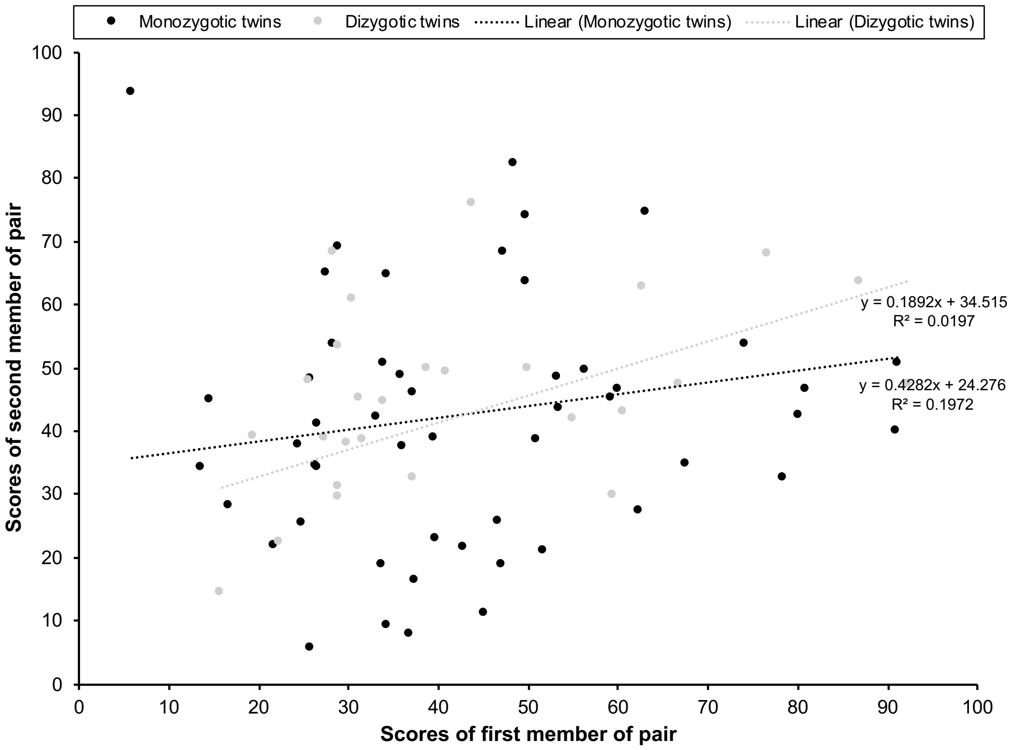
A scatter plot of the scores obtained by both zygosity groups for the memory functionality aspect of memory



Appendix I

Figure A7

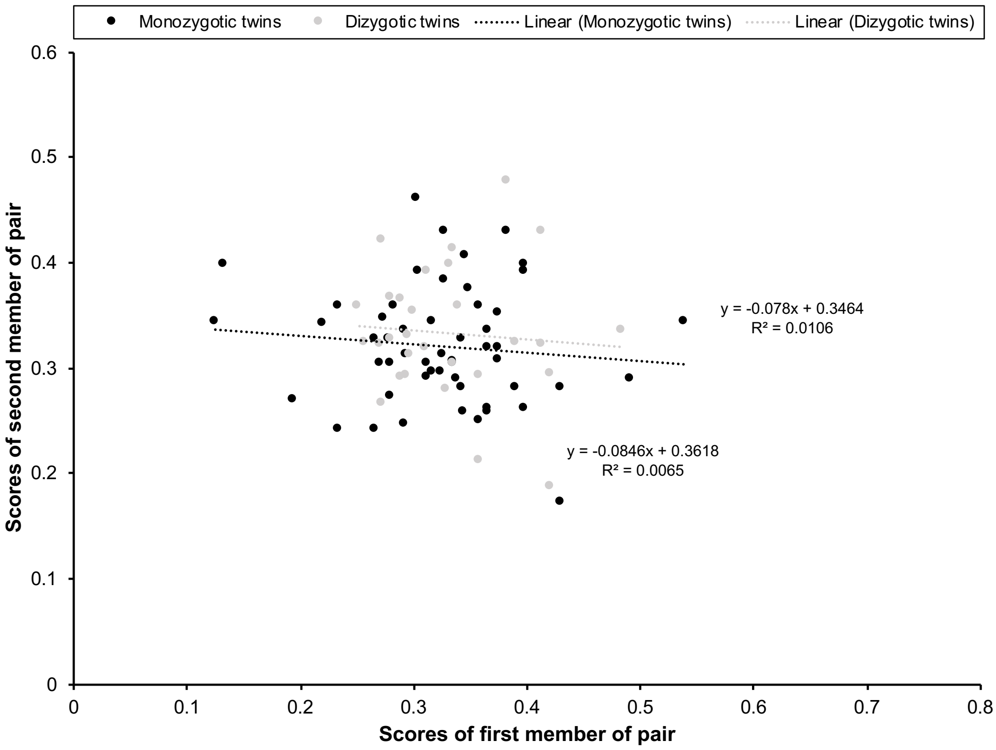
A scatter plot of the scores obtained by both zygosity groups for the inhibition aspect of memory



Appendix J

Figure A8

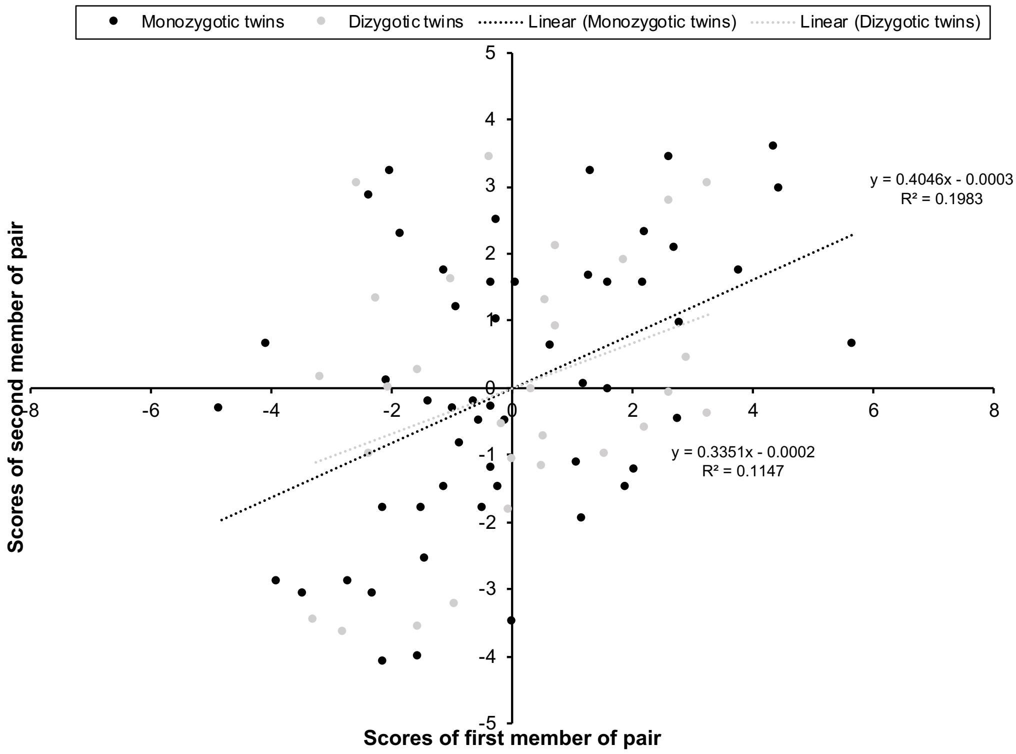
A scatter plot of the scores obtained by both zygosity groups for the mental flexibility aspect of memory



Appendix K

Figure A9

A scatter plot of the scores obtained by both zygosity groups for the working memory capacity aspect of memory

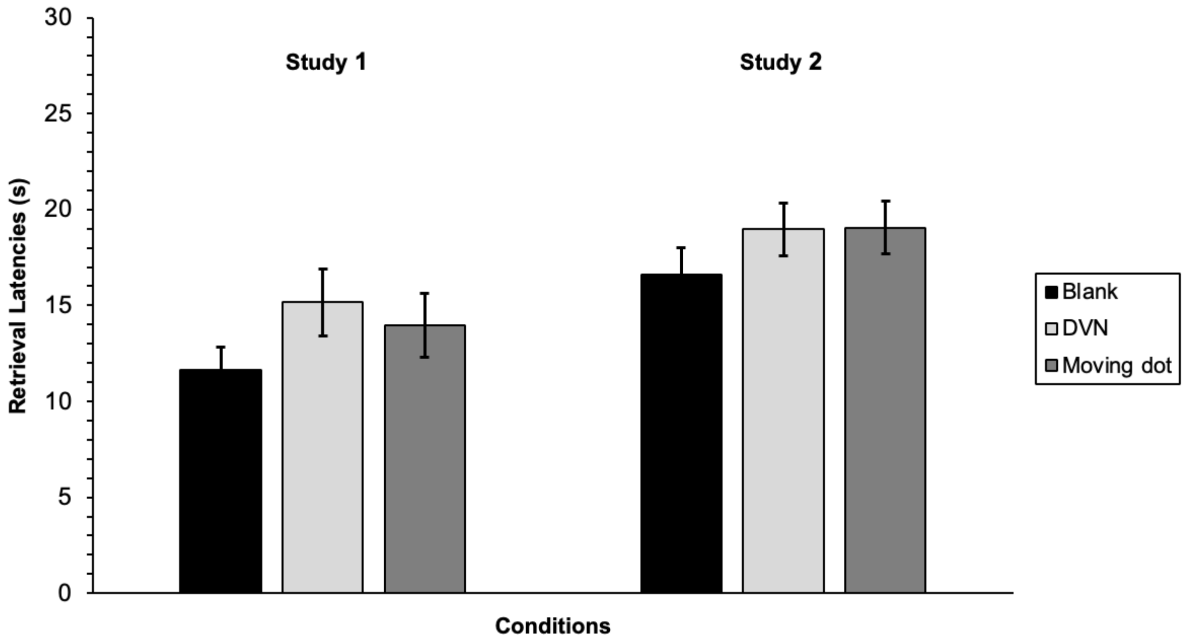


Note. Scatter plot values shown are standardized z-scores

Appendix L

Figure A10

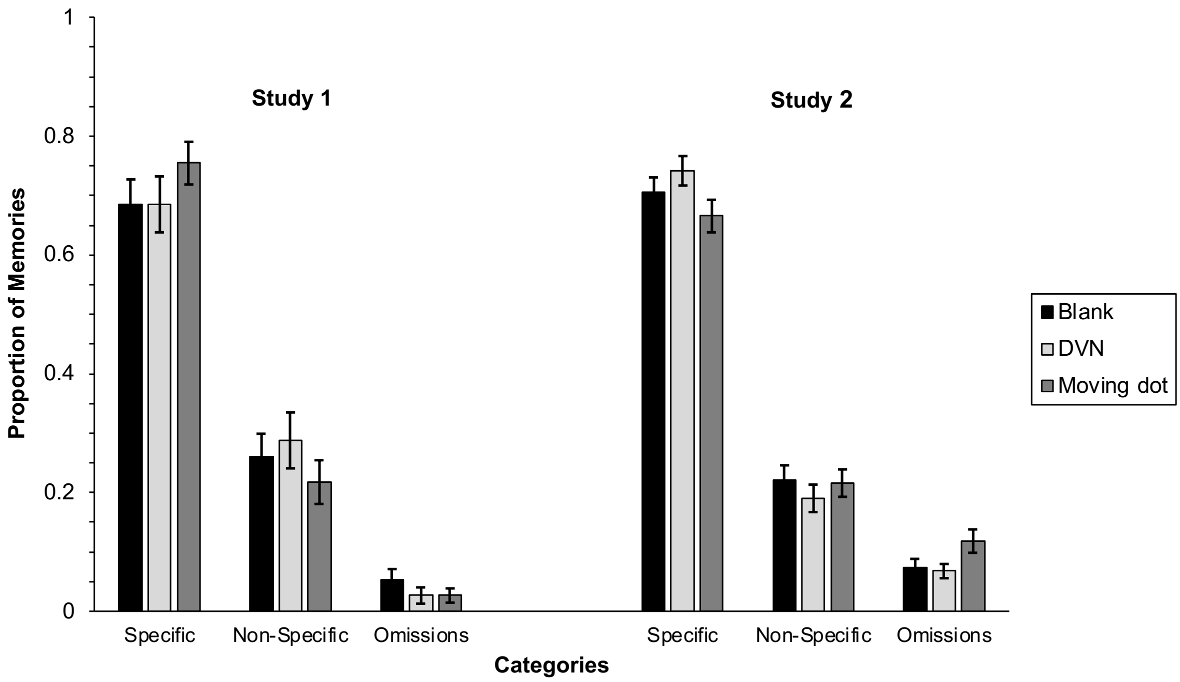
The retrieval latencies obtained across Studies 1 and 2 as a function of the different conditions. Error bars represent standard errors.



Appendix M

Figure A11

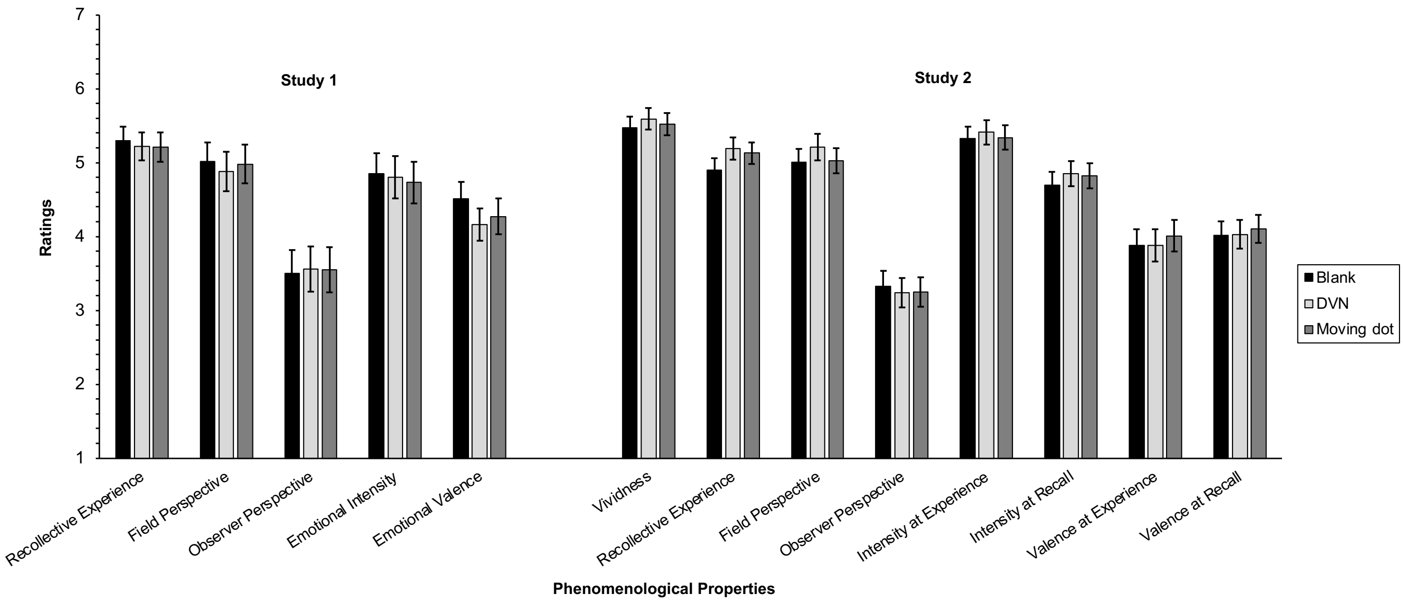
The proportion of specific memories, non-specific memories, and omissions retrieved across different conditions in Studies 1 and 2. Error bars represent standard errors.



Appendix N

Figure A12

The phenomenological properties of the memories retrieved across different conditions in Studies 1 and 2. Error bars represent standard errors.



Appendix O

Table A3

Items used to rate the different memory characteristics

Item	Rating scale
How vivid was the memory you just recalled?	Five-point Likert scale ranging from "vivid" to "very vivid"
While remembering the event, I felt as though I was reliving it	Five-point Likert scale ranging from "not at all" to "as if it were happening right now"
While remembering the event, I felt that I saw it out of my own eyes	Five-point Likert scale ranging from "not at all" to "completely"
While remembering the event, I felt that I saw it as an outside observer	Five-point Likert scale ranging from "not at all" to "completely"
While remembering the event, the emotions that I felt were extremely intense	Five-point Likert scale ranging from "not at all" to "completely"
While remembering the event, the emotions that I felt were extremely negative or extremely positive	Five-point Likert scale ranging from "very negative" to "very positive"
At the time of the event, the emotions I felt were extremely intense	Five-point Likert scale ranging from "not at all" to "completely"
At the time of the event, the emotions I felt were extremely positive or negative	Five-point Likert scale ranging from "not at all" to "completely"