# The role of the self in episodic memory: the effect of closeness to others

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Thesis submitted for PhD in Cognitive Neuroscience, 2018

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Declaration:

I, Yi-Jhong Han, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

# Abstract

It has been shown that processing information in relation to oneself as opposed to others benefits episodic memory. The cognitive and neural mechanisms underlying this self-reference effect (SRE) are mostly unknown. This thesis addressed these mechanisms by investigating (1) the effect of closeness to others on the SRE and (2) the electrophysiological activities associated with encoding and retrieving information about oneself. Three behavioural and two electrophysiological experiments are reported. In Experiment 1, healthy adults judged the degree to which trait adjectives described themselves, a close other or a distant other. Recognition memory for the adjectives showed a significant SRE for the self over both close and distant others. In Experiment 2, a source memory paradigm to elucidate the type of memory involved in the SRE again showed a significant SRE for the self relative to a close and distant other. In Experiment 3, subjective ratings of self-esteem and Big-Five personality traits were acquired to assess individual differences in the SRE. No significant correlations were found. In Experiments 4 and 5, memory-related brain activity was analysed via event-related potentials (ERPs) and oscillations. Retrieving information about oneself was associated with the mid-frontal and left-parietal ERP old/new effects, whereas retrieving information regarding a close other was associated with a late negative-going effect. Additionally, encoding information about oneself did not affect oscillatory power, but encoding information about a close or distant other was respectively associated with decreases in beta and theta power. In combination, the thesis suggests that (1) closeness to others does not explain the SRE and (2) there are distinct brain activities associated with the encoding and retrieval of information about oneself and others. The self thus seems a psychologically and anatomically specialised affiliation that affects information processing over time.

# Impact Statement

Episodic memory is one of the crucial cognitive functions in daily life. It involves the ability to memorise and recall details of events that happen to us, including the where, when, what, who and how of the events. The term ‘episodic memory’ has become one of the popular keywords in psychology and cognitive neuroscience since the term was coined by Endel Tulving (Tulving, 1972). However, there remain a large number of open questions that are awaiting to be answered. One of the unresolved issues concerns the relationship between the self and episodic memory: is information about oneself processed in the same manner as information about other people, or does the self have a special status in episodic memory?

This thesis investigates the role of the self in episodic memory. The thesis uses cognitive tasks that tap into different aspects of memory and experimentally-based measurements of performance in the tasks. In addition, electrical brain activity is measured from the scalps of healthy adults to investigate various stages of episodic memory. The aim was to reveal the brain activities that support the encoding into, and retrieval of, information about oneself as opposed to that of close and distant others. The results suggest that the self is a psychologically and neurally specialised affiliation that can affect information processing over time.

The findings presented in the thesis are beneficial to update knowledge in psychology and cognitive neuroscience, particularly in relation to the understanding of how social entities can modulate information processing. The insights provided in the thesis also have wider implications and may benefit cross-cultural studies. Different cultures have different perspectives on the self, falling somewhere on the spectrum between individualism and collectivism, and these views may affect how the self affects cognition in laboratories and in daily life in any culture. The thesis thus delivers a stepping stone to investigate the role of the self in a range of cultures.

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# Chapter 1. Introduction

This PhD thesis investigates the role of the self in episodic memory with behavioural and electroencephalogram (EEG) experiments. The thesis starts with an introductory chapter, followed by a methodology chapter of the techniques used in the experiments, event-related potentials (ERPs) and oscillations. Later chapters describe the methods and results of each individual experiment and the dissertation ends with a general discussion, revisiting issues from the results of the experiments. Two main research questions are addressed in this thesis: (1) what is the effect of closeness to others on the self-reference effect (SRE) and (2) what are the electrophysiological activities associated with encoding and retrieving information regarding oneself?

The introductory chapter starts by introducing relevant concepts in episodic memory, including the definitions, underlying mechanisms and how episodic memory can be measured. Then, the concept of the self is introduced, focusing on the self-reference effect (SRE), a phenomenon that people tend to remember information processed in relation to themselves better than information processed in relation to others. Previous findings and possible mechanisms are reviewed and summarised in this section. The next section covers a key concept that has been involved in the literature to the SRE, but which lacks a proper definition: closeness to others. The concept of closeness and how to use it to systematically evaluate the SRE are discussed in this section. The last two sections of the introductory chapter cover whether the self is special and the relationship between emotion, episodic memory and the SRE.

Chapter 2 is a methods chapter reviewing the strengths of using EEG and ERPs as tools to investigate episodic memory. With their excellent time resolution, these tools allow the brain activity associated with memory encoding and retrieval to be revealed. This chapter introduces fundamental concepts of the techniques and, importantly, encoding-related and retrieval-related activities found in previous EEG/ERP studies. Oscillatory activities related to episodic memory are covered in the second section of the chapter.

Chapters 3 to 7 describe the individual experiments. With negative, neutral and positive items, Experiment 1 used a key manipulation to measure the subjective closeness to others, demonstrating superior memory for the self than close and distant others. Experiment 2 investigated the types of memory that support the superior memory of the SRE with a source memory task. Experiment 3 investigated whether the memory differences between the self and others are due to an interaction between emotion and individual differences, using self-esteem and the Big-Five personality traits. Experiments 4 and 5 are EEG/ERP experiments investigating brain activities during encoding and retrieval of self-pertained information versus information about a close and a distant other.

The last chapter contains the general discussion of the data. It covers the implications of the findings and how these update our knowledge of the SRE. The chapter also covers more general issues in psychology and cognitive neuroscience.

## 1.1 Episodic memory

### 1.1.1 What is episodic memory?

Episodic memory is the ability to consciously recollect previous experiences from long-term memory (Tulving, 1972, 1985). For instance, “I remember seeing a flash of light a short while ago, followed by a loud sound a few seconds later (Tulving, 1972, p.386)”, a memory that contains events with their relationships in time. The concept of episodic memory is opposite to that of semantic memory, which is the ability to store general knowledge of the world without the involvement of personal experiences. An example of a semantic memory is “I remember that the chemical formula for common table salt is NaCl” (Tulving, 1972, p.387). The most crucial distinction between episodic and semantic memory is that the former involves information about where and when an event linked to oneself occurred, whereas semantic memory does not involve any of these elements (Tulving, 1984).

Another distinction between episodic and semantic memory is that the two have been linked to two levels of consciousness, autonoetic and noetic awareness, via case studies and recognition memory experiments (Tulving, 1985). Autonoetic awareness is the level of consciousness that involves personal experiences of past events and allows mental time travel, whereas noetic awareness is the sense of knowing that an event happened without the richness about its details. Any memory can be quantified by measuring the relative contributions of these two awareness levels during memory retrieval. In the context of Tulving’s framework, the Remember/Know procedure (detailed below) was designed to differentiate between these two conceptually distinct types of awareness.

In this procedure, experiments usually contain two phases, study and test. During the study phase, participants are instructed to remember a list of items, for example words or pictures. After a while, the studied items are intermixed with unstudied items and presented to the participants. They are instructed to indicate which of the items presented have been studied before by giving old and new responses. For those items receiving an ‘old’ response, a second decision is required to indicate whether the item is “remembered”, i.e. recognised because specific details from the study phase could be recollected, or “known”, recognised as being familiar but without being able to recollect details about the item’s initial occurrence (Tulving, 1985). Using this procedure, the recognition memory accuracy and the contribution of the two underlying processes can be measured and differentiated.

Remember/Know judgements and recognition memory performance are often quantified via a signal-detection model. According to this model, memory decisions are made according to the relationship between a decision criterion and distributions of memory strength of old and new items (Yonelinas, 2002; Yonelinas & Jacoby, 1995; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998). An “old” response will be made once the memory strength of a memory probe exceeds the predetermined criterion. Otherwise a “new” decision will be given, regardless of whether the item was actually old or new. In this manner, memory decisions can be categorised into one of four response categories based on the old/new status of a test item and the given response: hit, miss, false alarm, and correct rejection. If the item is old and its strength exceeds the criterion, the corresponding “old” response from the participant is called a ‘hit’. If the item is old but the strength does not exceed the criterion, a “new” response will be given, and this is called a ‘miss’. If the item is new and the strength of the item exceeds the criterion, the corresponding “old” response is categorised as a ‘false alarm’. Finally, if the item is new and its strength does not exceed the criterion, a “new” response is made and categorised as a ‘correct rejection’. Among the four recognition categories, hits and correct rejections are correct responses, whereas misses and false alarms are incorrect responses.

The term “response bias” refers to the placement of the criterion of when an ‘old’ response will be given. It has been shown that response bias affects recognition memory independently from memory strength (Snodgrass & Corwin, 1988). If participants adjust the placement of the criterion to a more liberal threshold, then more “old” responses will be given regardless of the old/new status of an item. On the contrary, if the placement of the criterion is shifted to a more conservative threshold, then more “new” responses will be given even when an item is in fact old. When memory strength is constant, a liberal criterion will result in higher hit and false alarm rates, whereas a more conservative criterion will result in lower hit and false alarm rate (i.e. higher correct rejection and miss rates). If the placement of a criterion is not adjusted to either a more conservative or liberal threshold (i.e. biased), the criterion is “unbiased” and has no effect to the responses given by the participants. Discrimination accuracy, the ability to differentiate between old and new items, can be measured by considering hit rates in combination with false alarm rates (Gardiner, 2001; Gardiner, Gregg, & Karayianni, 2006; Squire, Wixted, & Clark, 2007; Yonelinas, 2002). These proportions are affected by the distance between the distributions of memory strength of old and new items and the response criterion that is adopted. If memory is perfect, there is no overlap between the distributions of old and new items. With an unbiased criterion, a 100% hit rate and a 0%

false alarm rate would be expected. On the other hand, if memory is absent, which means the distributions of old and new items completely overlap, the hit rate and false alarm rates will be identical. With an unbiased criterion, the hit rate and false alarm rate will be at the chance level of 50%.

D-prime (d’) is a sensitivity measure that represents the distance between the old and new distributions (Banks, 1970; Dobbins, Khoe, Yonelinas, & Kroll, 2000; Yonelinas, 2002). It assumes that both distributions are normally distributed and placed on a single continuous dimension. The distance between the two distributions is determined by transforming hit rate and false alarm rate into z-scores, which is a standard score assuming both distributions are standard normal distributions (with mean of 0 and standard deviation of 1). After the transformation, the distance between the distributions is calculated by subtracting z(false alarm) from z(hit). In this manner, both hit rates and false alarm rates are taken into account at the same time and are transformed into one single number. A larger d’ represents a greater distance between the old and new distributions, hence better memory. For example, with hit rate 0.8 and false alarm rate 0.1, d’ equals z(hit) – z (false alarm), which is 0.84 - (-1.28) = 2.12. In another case, where the hit rate is slightly lower (0.7) with the same false alarm rate (0.1), d’ equals to 0.52 - (-1.28) = 1.81, which is smaller than the previous case, reflecting poorer discrimination ability.

In addition to d’, receiver operating characteristic (ROC) is another procedure that has been used to quantify recognition memory in the literature (Yonelinas, 1994, 1997, 2002; Yonelinas et al., 1998). A ROC analysis uses a two-dimensional figure illustrating the relationship between hit and false alarm rates. In this procedure, participants are instructed to give old/new recognition decisions based on different adaptations of their response criteria based on confidence, in a range of conservative to liberal. For example, in the most conservative condition, participants are instructed to give an “old” response only when they are sure that the presented test item is old. In the less conservative condition, they are instructed to give an “old” response when they think the presented item is old but are not sure. In the most liberal condition, participants are instructed to give a “new” response only when they are sure that the presented item is a new item. Lastly, in the less liberal condition, they are instructed to give a “new” response when they think the presented item is new but are not sure. In this case, a set of hit rates and false alarm rates based on various placements of the criteria can be acquired and plotted on a two-dimensional figure of hit rates and false alarm rates as a function of confidence levels. These ROC curves are then transformed into z-scores to examine whether the variance of the old and new distributions (the x- and y-axis) are equivalent (Yonelinas et al., 1998). If the variances of the old and new distributions are equivalent, the z-transformed ROC curve will be linear and symmetrical with a slope close to 1, which indicates there is a single and linear dimension behind the old and new distributions. Conversely, if the transformed z-ROC is not linear and asymmetrical, it suggests the variance of the old and new distributions are not equivalent (Glanzer, Kim, Hilford, & Adams, 1999; Ratcliff, Mckoon, & Tindall, 1994). These studies have shown that the ROC curve is symmetrical when the old/new decisions are based on a single process (i.e. familiarity, see next section), and asymmetrical when the decisions are based on two independent processes (i.e. familiarity and recollection, see next section). These patterns have been used to differentiate the processes supporting episodic memory (Yonelinas et al., 1998).

In addition to d' and Pr, another frequent way to indicate memory performance using a single number is via the two-high threshold model and 'Pr', a nonparametric measure of discrimination sensitivity (Snodgrass & Corwin, 1988). Pr is calculated by directly subtracting false alarm rates from hit rates, resulting in a single number that is simple to compute, easy to comprehend and able to represent accuracy to old items and error rates to new items at the same time. In the calculation of Pr, hit rate and false alarm rate are simplified while still taking bias into account (Feenan & Snodgrass, 1990; Snodgrass & Corwin, 1988). This approach has frequently been used to present memory performance in the literature (for example, Otten, Henson, & Rugg, 2001; Otten, Quayle, & Puvaneswaran, 2010; Pollak, Cicchetti, Hornung, & Reed, 2000; Wilding & Rugg, 1996) and will also be adopted in the present thesis.

### 1.1.2 Recollection and familiarity

One of the mainstream theories to account for episodic memory is the dual-process signal detection model (Yonelinas, 1994; Yonelinas, Aly, Wang, & Koen, 2010), which assumes that recognition memory decisions are supported by two underlying processes, recollection and familiarity (Atkinson & Juola, 1973; Jacoby & Dallas, 1981; Jacoby, Toth, Yonelinas, & Debner, 1994; Tulving, 1985; Yonelinas, 2002; Yonelinas & Jacoby, 1995). Recollection is a relatively slow and all-or-none process supporting the retrieval of qualitative information about previous events, for instance, where and when the event occurred or who was involved. If qualitative information is retrieved, participants will give an "old" decision to indicate that the current item was presented before. If no qualitative information is retrieved, then a "new" decision will be given as participants are not able to recognise the item. On the other hand, familiarity is a relatively fast and signal-detection-like process based on a single continuous dimension reflecting the subjective feeling of familiarity. Two Gaussian distributions are formed by the familiarity strengths of old and new items, respectively. The distance between the centres of the two distributions represents the sensitivity of familiarity. If the subjective feeling of familiarity to a presented item goes beyond a pre-determined criterion, then participants will give an “old” decision; If not, then a “new” decision will be given to the item. Under the assumption of this framework, recognition decisions are supported by both or either of the processes. Recollection and familiarity processes show different functional characteristics in past studies. Recollection requires more attentional control and more time to initiate. Familiarity is a relatively automatic process than recollection, and it is also faster, resulting in faster reaction times than recollection (Gardiner et al., 2006; Gregg, Gardiner, Karayianni, & Konstantinou, 2006). These characteristics have been demonstrated by the Remember/Know procedure (Tulving, 1985) in past studies, in which Remember responses indicate the contribution of recollection, while Know responses indicate the contribution of familiarity (see next section).

Whether recollection and familiarity are one process with two criteria, or two distinct processes, has been intensely debated in the literature. Early studies proposed that Remember and Know responses are differentiated by conceptual and perceptual processing, instead of reflecting two functionally distinct processes (Roediger, Weldon, & Challis, 1989). However, it has been demonstrated that the proportion of Remember responses is sensitive to a higher degree of distinctive processing (for example, different levels of processing), and the proportion of Know responses is sensitive to processing fluency (Rajaram, 1993, 1996), regardless of whether the process is conceptual or perceptual. It has also been demonstrated that Remember responses are correlated with high confidence decisions, whereas Know responses are correlated with low confidence decisions (Wixted & Stretch, 2004). This correlation supports the distinction between Remember and Know responses as reflecting two criteria on a single-dimension, with a conservative criterion for Remember and a liberal criterion for Know responses (W. Donaldson, 1996). However, there are large numbers of follow-up studies suggesting that the confidence of the decisions and the proportions of Remember/Know responses are functionally dissociable and not reflecting different strengths or confidence of the same process (Dobbins et al., 2000; Gardiner & Java, 1990; Perfect, Mayes, Downes, & VanEijk, 1996; Rajaram, 1993; Yonelinas, 2002; Yonelinas et al., 1998).

The dissociation of recollection and familiarity also emerged in terms of neuronal populations (Yonelinas, 2002; Yonelinas et al., 2010). By using the Remember/Know procedure, functional imaging studies have suggested that, during the engagement of recollection, a more ventral part of the left posterior parietal cortex (PPC) is activated, while the activation is more dorsal for the engagement of familiarity (Frithsen & Miller, 2014; Vilberg & Rugg, 2007). In addition to functional imaging studies, studies using event-related potentials (ERPs) have demonstrated electrophysiological dissociations of recollection and familiarity (Allan, Wilding, & Rugg, 1998; Duzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Paller & Kutas, 1992; Rugg & Curran, 2007; Wilding & Rugg, 1996; Woodruff, Hayama, & Rugg, 2006). Recollection has been correlated with a left-parietal old/new effect around 500-800 ms after item onset, whereas familiarity has been correlated with a mid-frontally distributed old/new effect at an earlier time window, 300-500 ms (relevant reviews will be covered in the EEG chapter).

### 1.1.3 How to measure recollection and familiarity?

There are two major ways to quantify recollection and familiarity during memory retrieval, the Remember/Know procedure mentioned earlier and the source memory paradigm. As denoted above, the Remember/Know procedure demands participants to give further information about their recognition memory judgments, as to whether the decision is based on the retrieval of specific contextual details, or purely a feeling of familiarity. This approach has been considered to be an effective and efficient way to quantify the subjective contributions of recollection and familiarity to memory retrieval, as long as the participants follow the introspective instructions properly (Yonelinas, 2002; Yonelinas et al., 2010).

Other than the Remember/Know procedure, another frequent way to quantify the relative contributions of recollection and familiarity during memory decisions is the source memory paradigm. The structure of this procedure is similar to that of the Remember/Know procedure but with a source memory instead of Remember or Know judgments following the old/new judgments. This is usually accomplished by adding specific information to the study items during the preceding study phase. The additional feature can be, for example, the colour in which a study item is presented (MacKenzie, Powell, & Donaldson, 2015), the type of task performed on the item (Addante, Watrous, Yonelinas, Ekstrom, & Ranganath, 2011), the location of the item on the screen (Harlow & Donaldson, 2013), or the temporal order of the item relative to other items (Frithsen & Miller, 2014; Yick, Buratto, & Schaefer, 2015). In addition to the different sources, a “don’t know” option is often included in the response options to capture the situation when participants cannot recall the source. This variation prevents source accuracy to be inflated due to the undesirable contribution of guessing (Vallesi & Shallice, 2006; Wilding & Rugg, 1996). In this case, the proportion of recollection is usually reflected by the proportion of correct source responses, as opposed to source incorrect and guess responses.

Given that the accuracy of source memory is relatively well operationalised relative to the subjectively reported details in the Remember/Know procedure, the source memory paradigm is more objective than the Remember/Know procedure. However, the source memory approach can underestimate the contribution of recollection, as there might be episodic information retrieved during the decision process other than the sources of interest. This issue has been raised as the ‘non-critical problem’ of the source memory paradigm (Yonelinas & Jacoby, 1996). Also, the source memory paradigm is more top-down demanding, which requires more attentional control and orientation toward retrieval (Frithsen & Miller, 2014). On the other hand, the Remember/Know procedure has been critiqued of exclusively relying on participants’ subjective awareness of contextual details, which does not provide a way to verify the classifications and only relies on the pre-test training and practice (Roberto Cabeza, 2008; W. Donaldson, 1996; Frithsen & Miller, 2014; Yonelinas et al., 2010).

## 1.2 Self-referencing in memory

### 1.2.1 What is the self?

The experiments reported in this study consider the role of the self in episodic memory. The concept of the “self” varies in different psychological domains. In psychology, one of its definitions is “the sum total of an individual’s beliefs about his or her own personal attributes” (Brehm, Kassin, & Fein, 2005, p.56). Such sums of attributes consist of “self-schemas”, which are beliefs about oneself that provide fundamental guidance when processing self-relevant information (Markus, 1977). For instance, an individual can form the identity of his or herself by standing in front of a mirror and getting to know the characteristics of his or her appearance from the image, such as the height, skin colour, hair style or facial expressions. In this case, he or she can form a knowledge set about his or her own appearance. Not only physical characteristics can be used as the basis for the self, but also mental and abstract concepts can be part of the self-schema, such as knowing the capability when facing new challenges or his/her personality attributes. Those sets of knowledge provide the basis for knowing an individual’s own self and are essential for anyone who would like to differentiate themselves from others.

The self is not only determined by knowing the attributes of oneself, but also via comparisons with others, the social comparisons (Brehm et al., 2005; Corcoran, Crusius, & Mussweiler, 2011; Festinger, 1954). In the theory of social comparisons, a person will compare his or her attributes, fortune, or life experience with a similar someone to know who they are and establish his or her self-identity with the results of the evaluation. In addition, people tend to highlight those characteristics that make themselves distinct from their fellow groups (Kite, 1992). For instance, a male student in a class formed by mostly female fellow students may highlight the fact that he is a male, when he is asked to introduce himself. Moreover, due to the tendency of maintaining a positive figure of oneself or seeking self-improvements, sometimes the social comparisons are made against people who compare less or more favourably to oneself. When comparing downwards, the positive figure of the self is maintained by feeling superior to a less capable other; when comparing upwards, the positive figure is maintained by feeling at the same level of a more capable other (Taylor & Lobel, 1989; Wills, 1981). By engaging in social comparisons, an individual can efficiently gain his or her self-knowledge (Epstude & Mussweiler, 2009).

### 1.2.2 Autobiographical memory and the self

Along with self-schemas and social comparisons, autobiographical memory (a form of episodic memory) also contributes to parts of the self-construct. Memory builds one's self-identity over time and is crucial for a person to maintain the awareness that he or she is the same person over time (the sense of continuity; Conway, 2005; Conway & Pleydell-Pearce, 2000; Nelson, 2003; Nelson & Fivush, 2004; Pasupathi, Mansour, & Brubaker, 2007). Autobiographical memory has two parts that are considered together in the context of the self-construct: memory for specific episodes and the knowledge of one's own life and autobiographical knowledge (Williams, Conway, & Cohen, 2008). Examples of the latter are the house one lived in when he/she was a child, the first time going to school and what made the scar on the knee. This information not only involves episodes that happened in the past, but also semantic information in the form of knowledge. In addition, these single nodes in the past can be easily extended to other related episodes or information. For example, one might remember that there was a small garden in front of the house, where a summer party took place with one of the neighbours and that he/she was too shy to talk to the guests. In this example, the information started from the house where the individual lived, and then extended to the summer party, and the knowledge that he/she was shy but is now more social. An individual can use this memory system to construct and keep his or her self-identity over time and, importantly, this system also provides the information needed for the social comparisons mentioned above (Brehm et al., 2005; Corcoran et al., 2011).

### 1.2.3 Self-reference effect (SRE)

The self-reference effect (SRE) is a memory phenomenon that people remember information bounded to themselves better than information bounded to others. For example, if you go to a pub with colleagues after work, you afterwards are more likely to remember what beer you had yourself than your colleagues.  The core part of this phenomenon, the self, has been demonstrated to be an important part in various aspects of human cognition, including emotion (Ochsner et al., 2004; Schimel, Arndt, Pyszczynski, & Greenberg, 2001; Taylor & Lobel, 1989), social interaction (Corcoran et al., 2011; Howell & Shepperd, 2017) and episodic memory (Klein, 2012; Sui & Humphreys, 2015; Symons & Johnson, 1997).

The SRE was first demonstrated in the laboratory by Rogers, Kuiper, and Kirker (1977) in that information correlated to the self was remembered better than information encoded with other ways. In two experiments, Rogers et al. (1977) presented trait adjectives to participants and asked them to judge whether the item describes themselves (the Self-Reference or SR task), is meaningful (the meaningfulness task), means the same as another word (the semantic task), rhymes with another word (the phonetic task) or consists of big letters (the structural task). The results suggested that the SR encoding yielded the highest recall performance and fastest reaction time among the encoding tasks. Even when compared with a meaningfulness task, which claimed to match the depth of encoding with the SR task, the recall performance of the SR task was better than the meaningfulness task. The demonstration of the SRE raised two important issues in the scope of human cognition. Firstly, is SR an effective way of memory encoding? If so, what is the relationship between SR and general memory characteristics, for example levels of processing (LOP, Craik & Lockhart, 1972)? Secondly, what is the role of the self in human cognition? Is it a specialised concept or the closest spot on a continuous spectrum of distance to others, compared to a close other and a distant other? These issues have been explored in subsequent studies.

The SRE was replicated in subsequent studies, and more information about the factors affecting the SRE was revealed. For example, in Maki and McCaul (1985), the SRE was demonstrated by comparing the recall performance of SR encoding with other person-referencing (OR) tasks, including close others (mother or a friend) and a distant other (a celebrity, Ronald Reagan, the 40th president of the US). The results showed striking patterns of the SRE based on the materials used: when trait adjectives were used as memory materials, SR encoding facilitated memory compared to OR encoding, but when nouns were used as materials, the SR did not facilitate memory. The reason was thought to be that traits are part of self-schema (Markus & Smith, 1981), but nouns are not, hence only traits are encoded beneficially in a SR task (Maki & McCaul, 1985).

In addition to the effect of materials, a follow-up investigation of the SRE (Klein & Loftus, 1988) provided insights into the underlying processes: the SR might include at least two memory-related processes during encoding, elaboration (i.e. whether the word meaning is as same as another word, Rogers et al., 1977) and organisation (i.e. whether the word is self-descriptive, Klein & Kihlstrom, 1986). During encoding involving elaboration, the item-specific information is connected to items outside the list (e.g., processing ‘music’ might be related to the experience of buying an album in real life), hence enhancing memory by providing more possible routes during retrieval. On the other hand, organisation promotes inter-item relationships in the same study list. In the case of asking participants whether an item is self-descriptive, participants form the organisation by labelling items into categories of being self-descriptive or not. The results from Klein and Loftus (1988) suggest that both processes are involved during SR and result in better memory when comparing with encoding tasks involving only one of the processes (for example, semantic encoding, which involves only elaboration). Additionally, it was suggested that the contribution of the two processes depends on the inter-item relationship of the memory lists. If the items on the list are interrelated to a similar concept (e.g., 'jazz' and 'opera', both types of music), then an elaborative encoding (e.g., think of the definition of the item) will boost memory by adding more item-specific information (e.g., piano and saxophone playing are related to 'jazz') on top of the pre-existent interrelationship between the items (i.e. 'jazz' and 'opera', both types of music). As a result, elaborative encoding will result in better memory than organisational encoding (e.g., sort the item to the category where it belongs), which promotes existent inter-item relationship but lacks adding item-specific information to memory. In contrast, if the items on the encoding list are not interrelated (e.g., 'band' and 'weekend', both are related to 'party' but not in the same category), then tasks involving organisational processes will boost memory by promoting participants to create associations between the items on top of the information bound to the individual items. In this case, due to SR involving both elaborative and organisational processing, memory is enhanced regardless of the interrelationship between the items and results in better memory than encoding tasks that involve only one of the processes (Klein & Loftus, 1988).

The idea that the SRE involves both elaborative and organisational processing was supported by a meta-analysis. Symons and Johnson (1997) reviewed studies relevant to the SRE and concluded that the reason behind the SRE is that both elaboration and organisation of the encoded information are promoted, compared to other person referencing and semantic tasks, which involve either only organisational or elaborative processes. In addition, Symons and Johnson (1997) further addressed whether intimacy to others, but not familiarity to others (for example, Maki & McCaul, 1985), predict the effect size of SRE. When comparing SR encoding with OR encoding, lower intimacy to the person during OR encoding results in larger differences between SR and OR conditions and a larger SRE. Based on this meta-analysis, several insights and concerns emerged. First and foremost, previous studies frequently used a variety of "others" as opposed to the self to produce the SRE, for example one's mother (Keenan & Baillet, 1980; Maki & McCaul, 1985), best friend (Keenan & Baillet, 1980; Maki & McCaul, 1985) or a celebrity (Keenan & Baillet, 1980; Maki & McCaul, 1985; Wells, Hoffman, & Enzle, 1984). However, whether the “other” conditions used in studies varied in terms of intimacy or familiarity was not properly differentiated. Furthermore, not only the differentiation itself, but also the concepts of intimacy and familiarity in these studies were not properly defined. For example, in Keenan and Baillet (1980) and Maki and McCaul (1985), the necessity of differentiating levels of familiarity to others when producing the SRE was emphasised. However, they did not provide any quantification of familiarity levels (e.g., how does one’s mother differ from President Ronald Reagan in terms of their levels of familiarity?). Similarly, in another study, Aron, Aron, Tudor, and Nelson (1991) highlighted the importance of considering levels of intimacy when utilising OR and SR in experiments. However, a proper measurement to support levels of intimacy was also missing.

Second, the type of memory test may affect whether the SRE is prominent. Studies using recall yielded larger SREs than studies using recognition. However, in Symons and Johnson (1997)’s meta-analysis, most considered studies used recall (recall vs recognition: 105 vs 22) as their memory test. There were relatively few studies using recognition memory before their meta-analysis, which left an uncertainty as to whether the SRE using recall would generalise to recognition and other types of episodic memory tests. Third, the review by Symons and Johnson (1997) showed that types of memory materials affect the prominence of the SRE, interacting with the other parameters discussed above. Overall, trait words were used more often than noun words. When nouns were used as memory materials, the difference between SR and OR was minimal or even equal, while both were remembered better than semantic encoding in most cases. When adjectives were used as memory materials, SR outperformed OR and semantic encoding. Nevertheless, when memory following SR was compared with that of a familiar other rather than a distant other, the SRE was smaller and sometimes disappeared. Fourth, Symons and Johnson (1997) highlighted that SR encoding should be compared with OR but not semantic encoding because SR involves social entity, whereas semantic processing does not. This means that SR is more similar to OR than semantic encoding tasks. Thus, to provide a better baseline condition, OR is more appropriate than a semantic task. Lastly, studies have suggested what cognitive processes may underlie the SRE, including semantic processing, elaborative processing, and organisational processing. However, none of these was conclusive at this time point, leaving the mechanisms of the SRE under debate.

After Symons and Johnson (1997)’s review, there were only relatively few studies (Czienskowski & Giljohann, 2002; D'Argembeau, Comblain, & Van der Linden, 2005; Magno & Allan, 2007; Mu & Han, 2010) which extended the investigation of the SRE in episodic memory until Klein (2012), the next periodical review on the SRE. It was highlighted that the diverse methodological details between studies make it difficult to identify the processing behind the SRE. Klein (2012) proposed that the SRE is not a single phenomenon but a family of effects, each caused by the different designs and materials used. When looking into SRE studies, it is thus necessary to consider the details of the experimental design and the self concepts that are tested. Klein (2012) further proposed that two different self concepts should be taken into account when investigating and interpreting the effect of the self in human cognition: the ontological self and the epistemological self. The ontological self refers to the subjective agency and experience of being a 'self', which contributes to the subjective internal thoughts and external sense of behavioural control and is difficult to describe and operationally define. On the other hand, the epistemological self refers to the neurological basis of the self, which is responsible for the behaviour and knowledge of the organism. Under this distinction, only the epistemological self can be operationally tested, as the behaviour (e.g., reaction times of a certain cognitive task) and knowledge (e.g., does it describe you?) can be measured. This differentiation clarified the diverse and striking results in the literature of the SRE.

Recent studies on the SRE covered areas which were not addressed in the past, including the SRE in clinical populations (Compere et al., 2016; Fomina et al., 2017; Leblond et al., 2016; Li et al., 2017), aging (Carson, Murphy, Moscovitch, & Rosenbaum, 2016; Degeilh et al., 2015; Gutchess et al., 2015; Leblond et al., 2016), individual differences and emotion (Caudek, 2014; Durbin, Mitchell, & Johnson, 2017; Jones & Brunell, 2014), and associated brain activity (Allan, Morson, Dixon, Martin, & Cunningham, 2017; Degeilh et al., 2015; Gutchess et al., 2015; Yamawaki et al., 2017). It has been shown that an SR task with concrete object pictures (is it pleasant to you?) can benefit recollection for old as much as young individuals when compared with semantic encoding (is it common?; Dulas, Newsome, & Duarte, 2011; Leshikar, Dulas, & Duarte, 2015). It was also found that SR encoding benefits recall of positive traits more than negative traits, due to the phenomenon of mnemic-neglect (i.e. the tendency to avoid negative traits; Green, Pinter, & Sedikides, 2005; Pinter, Green, Sedikides, & Gregg, 2011). These studies have started to illuminate the generalizability of the SRE effect and its underlying mechanism or mechanisms.

Brain imaging studies have also shed light on the nature of the SRE. There have been studies showing that the medial prefrontal cortex (mPFC) is involved in self-referenced memory (Bergström, Vogelsang, Benoit, & Simons, 2015; Kelley et al., 2002), but not other-referenced memory. This is true for both young and old individuals (Gutchess, Kensinger, & Schacter, 2007; Gutchess et al., 2015). In addition, functional imaging studies using the subsequent memory paradigm (Paller & Wagner, 2002) have investigated brain activity during SR encoding. These studies suggest that old and young groups show similar encoding-related activity in the mPFC (Gutchess, Kensinger, & Schacter, 2010; Gutchess, Kensinger, Yoon, & Schacter, 2007; Leshikar & Duarte, 2014). It has been shown that retrieving information about the self is related to functional connectivity between cortical regions and the ventral mPFC, which is part of the default-mode network (DMN; Andrews-Hanna, 2011). The DMN is a set of midline and cortical brain regions that increase their activity during idle moments during experimental tasks. The DMN is related to the monitoring of external events (S. J. Gilbert, Dumontheil, Simons, Frith, & Burgess, 2007; Hahn, Ross, & Stein, 2007) and the evaluation of internal thoughts, such as previous memory episodes (H. Kim, Daselaar, & Cabeza, 2010; Vannini et al., 2011). The link between memory-based processing and the DMN has been shown to be specifically related to the medial temporal lobe (MTL) subsystem of the DMN (Buckner, 2010; D. T. Gilbert & Wilson, 2007; Schacter, Addis, & Buckner, 2008), which, in addition to the mPFC, supports the retrieval of self-referenced information (D'Argembeau, Collette, et al., 2005; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Mitchell, Banaji, & Macrae, 2005; Northoff et al., 2006). Specifically, it has been shown that better memory for information processed in relation to oneself is correlated with stronger functional connectivity between the mPFC and MTL, which has been linked to more automatic memory retrieval. In contrast, better memory for information processed in relation to a close other has been correlated with stronger functional connectivity between lateral prefrontal and parietal regions, linked to more controlled memory retrieval (de Caso et al., 2017). These brain imaging studies have shown that encoding and retrieving information about oneself versus others is associated with spatially and functionally distinct regions in the brain.

The numerous findings that the self can benefit memory performance have raised the interests of different kinds of researchers and given rise to the following general question: what is the nature of the self? Is the self a special concept distinct from other universal psychological concepts? If the answer to this question is yes, then what are the unique characteristics of the self? Although the seminal study of Rogers et al. (1977) revealed the characteristics of the SRE to some extent, there remain many pieces of missing information. In addition to the research on the SRE, research has focused on the role of the self in cognition more generally and indicated that the self has a distinct role in binding information (Sui, 2016; Sui & Humphreys, 2015) and biasing attentional processes (Conway, Pothos, & Turk, 2016). The benefits on episodic memory are thus not the only case where the self shows an advantage. However, in a recent study (Allan et al., 2017), it has been shown that during memory retrieval, participants tend to confuse the source of objects as either themselves or a close other, but not a distant other (the 'source confusion': Allan et al., 2017; Benoit, Gilbert, Volle, & Burgess, 2010; Bergström et al., 2015). This finding may raise doubts as to whether the self is a specialised concept in human cognition. Moreover, it is not yet clear how the self operates in the cognitive system. A methodological concern, as addressed earlier, is that a proper comparison is needed to show the beneficial effects of the self. Previous studies lack a proper quantitative definition of how familiarity or intimacy with others is determined. This issue makes results less consistent and interpretable across studies, preventing a full understanding of the role of the self in episodic memory. On a final note, although there are several studies that have addressed brain activity during retrieving information in relation to the self (Bergström et al., 2015; D'Argembeau, Comblain, et al., 2005; de Caso et al., 2017; Gutchess, Kensinger, Yoon, et al., 2007; Leshikar & Duarte, 2014), brain activity during encoding has received less attention (e.g., Gutchess, Kensinger, & Schacter, 2007; Gutchess et al., 2010; Yamawaki et al., 2017). There thus remain many questions to be answered about the role of the self in memory, and cognition more generally.

### 1.2.4 Possible mechanisms of the SRE

One of the core questions about the SRE is how self-referencing benefits memory, and how it interacts with other memory characteristics. As discussed previously in this chapter, early accounts of the SRE are based on effects of the materials used (Maki & McCaul, 1985) and types of tasks during encoding (Klein & Loftus, 1988; Symons & Johnson, 1997). It was shown that the superior memory for the self is a result of multiple factors, including processing materials in relation to the self-construct, which does not exist when processing focuses on other people (Maki & McCaul, 1985), and employing elaborative and organisational processes (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997). The relevance of the self-construct has been the centre of attention. When the materials or tasks require access to information about the self, the event is prioritized over other events. In terms of brain activity, as explained in the previous section, the mPFC is a region that has been shown to be involved specifically during SR encoding (Kelley et al., 2002) and retrieval (Bergström et al., 2015; D'Argembeau, Comblain, et al., 2005; de Caso et al., 2017; Gutchess, Kensinger, Yoon, et al., 2007; Leshikar & Duarte, 2014). The DMN has also been implicated in the construct of the self (D'Argembeau, Comblain, et al., 2005; de Caso et al., 2017).

Taking these findings together, it seems that the self has a special processing route at the levels of both mental processing and functional connectivity in the brain. These make the information distinct from other processing sources, hence enhancing memory. Having said that, the reasons for the difference in memory for the self versus others is not yet clear given the diversity in findings and many factors that seem to affect the SRE.

Crucially, a better description and definition of what differentiates the self and others should help understand the superiority of the self in memory. The following sections consider one such factor, namely closeness to others.

## 1.3 Closeness to others

The term ‘intimacy’, which is a concept that lacks a proper definition but has been used extensively in the literature, is considered to be an important factor in the SRE (Czienskowski & Giljohann, 2002; Keenan & Baillet, 1980; Klein, 2012; Maki & McCaul, 1985; Rogers et al., 1977; Symons & Johnson, 1997; Wells et al., 1984). In previous studies, people with varying levels of intimacy were used as controls to contrast memory for the self. For example, one’s mother (Keenan & Baillet, 1980; Maki & McCaul, 1985), best friend (Keenan & Baillet, 1980; Maki & McCaul, 1985) or a celebrity (Keenan & Baillet, 1980; Maki & McCaul, 1985; Wells et al., 1984) have been used as the “other” person, where mother or best friend are arguably more intimate than a celebrity (Keenan & Baillet, 1980; Maki & McCaul, 1985). However, in terms of what makes a mother and a best friend more intimate, this has not been properly defined and measured.

Below, I introduce the concept of closeness to others, which has often been used interchangeably with intimacy (Aron, Melinat, Aron, Vallone, & Bator, 1997; Helgeson, Shaver, & Dyer, 1987; McAdams, 1988; Reis & Shaver, 1988). I will discuss the literature on closeness and propose a solution that may be helpful when differentiating others in the context of the SRE.

### 1.3.1 What is closeness to others?

Closeness is a subjective feeling of being close to another person, the sense of ‘including other in the self’ (Aron et al., 1991; Aron et al., 1997). The closeness to others can affect interpersonal interactions in at least three ways (Aron et al., 1991). First, closeness changes the allocation of resources. More resources will be allocated to people who are subjectively considered closer than to people considered less close. Second, people tend to make fewer distinctions between themselves and close others, resulting in a more integrated sense of ‘we-ness’ (McDonald, 1981). Third, people tend to share the characteristics of a close other more than with a less close other. For example, an individual is more likely to celebrate a happy achievement from a closer friend instead of a less close friend.

Another definition of closeness to others is more practical, including amount of time spent together, shared activities and mutual influences (Berscheid, Snyder, & Omoto, 1989). This definition involves two levels of information: behaving close and feeling close (Aron,

Aron, & Smollan, 1992). ‘Behaving close’ refers to knowledge-based understanding that the closer you are to a person, the more likely he or she is to know your habits, personality, daily routines and private characteristics. ‘Feeling close’ refers to emotion: the closer you are to a person, the more emotionally attached you are to that person.

### 1.3.2 How to measure the closeness to others?

In addition to a measure of closeness to, or intimacy with, someone else, it is necessary to be able to measure the distance between one self and another. Any proper measure to indicate degree of closeness should cover the degree of emotional attachment to another person. This is often measured with familiarity, the knowledge about the other person, in closeness scales developed in the past (Aron et al., 1992; Berscheid et al., 1989; Gachter, Starmer, & Tufano, 2015; Sternberg, 1997). For example, the Subjective Closeness Index (SCI; Gachter et al., 2015) and Inclusion of Other in the Self (IOS; Berscheid et al., 1989) scale instruct participants to indicate their closeness to a designated other using a 7-point scale, from ‘not close at all’ to ‘very close’. In another example, the Relational Closeness Inventory (RCI; Berscheid et al., 1989) instructs participants to indicate the amount of intellectual influence from another person, for example, the amount of time, variety of interactions and degree of perceived influences of the other person on his or her own decision, activities and plans. In this case, in a simple method to differentiate whether one person is closer than another person to the individual, scores of subjective closeness and intellectual knowledge of other people can be acquired. Using these scores, the subjective closeness to others can be differentiated properly and objectively. In SRE research, parents or a close friend are often assigned as the other condition to serve as the comparison with the self (e.g., Czienskowski & Giljohann, 2002; Rogers et al., 1977). However, closeness scales were not typically used in these studies, making it difficult to know whether a participant’s mother is indeed a close other, or whether the mother is closer than a close friend, for example.

### 1.3.3 The differentiation between closeness and familiarity

A concept that is similar to, but different from, closeness is “familiarity”. Familiarity refers to the degree to which one knows another person and is what is used in the closeness scales discussed in the previous section. It has been shown that familiarity has a linear effect on memory: the more familiar a person is, the better is memory for items linked to that person (Keenan & Baillet, 1980; Maki & McCaul, 1985). However, familiarity and closeness are often confounded in previous work, making it unclear which gives rise to the better memory (Symons & Johnson, 1997). By acquiring separate measures for subjective closeness and intellectual knowledge of the other person, the subjective familiarity and closeness can be differentiated. This differentiation gives researchers the means to vary the “other” condition in terms of both or either, allowing an unravelling of their relative contributions to memory. This would remedy the issue of confounding closeness and familiarity, which has been a major criticism of early SRE studies (Symons & Johnson, 1997).

In order to investigate whether the self or the closeness to others is a key factor underlying the SRE, a range of encoding conditions can be used: (1) the self, (2) a familiar and close other and (3) a familiar but distant other. In this case, any difference between the self and a close other should not be because of familiarity as this is kept constant. The ‘distant other’ condition has a lower level of closeness compared to both the self and a close other. It has been shown that closeness and familiarity are dissociable in a relationship: one can have a relationship that consists of practical commitment with knowledge about the other person but a lack of emotional intimacy and passion (the empty love), or the other way around (the romantic love) (Acker & Davis, 1992; Sternberg, 1986, 1997). In the context of the SRE paradigm, a condition of high familiarity but low closeness can be achieved by employing a fictional character that participant is familiar with. It has been shown that fictional episodes elicited lower level of subject emotional experience compared to real life events (LaMarre & Landreville, 2009; Sperduti et al., 2016). In this case, fictional characters are able to provide as a familiar but less close control to the self and a close other. There have been studies suggesting that there is a hard emotional boundary between a fictional character and a real person, which enables individuals to differentiate between emotions in real life and fiction (Sperduti et al., 2016; Walton, 1978, 1990). For example, while seeing a scary movie in the cinema, fear might be engaged because of the episode. However, people do not become panicked due to the scary episodes in the movie. Due to these boundaries between real life and fictional episodes, fictional characters have been eligible to be used as a less close contrast for the self and a close other in real life. Details of this manipulation are covered in the respective methods sections of later chapters in the thesis.

## 1.4 Is the self special?

As briefly mentioned earlier, the observation and investigation of the SRE in the literature have led to a more general interest: is the self a special concept? What is the relationship between the self and a close other in the context of human cognition? Studies have suggested that the self sometimes gets confused with close others (e.g., Allan et al., 2017; Aron & Aron, 1986), which blurs the boundary between the self and others.

However, other researcher argue that, even in extreme cases, others will not become the self, because self-awareness and the sense of agency are two core elements of the self that are not possessed by any form of others (Decety & Sommerville, 2003). In addition, evidence from neuroimaging techniques has shown that self-related processing involves brain areas that are distinct from other-related processing (Bergström et al., 2015; de Caso et al., 2017; Kelley et al., 2002). Given the limited and diverse findings in the literature, it is difficult to reach a clear-cut conclusion at the moment as to whether the self is special (e.g., Gillihan & Farah, 2005).

In more recent studies, the self has been proposed as a binding function that links psychological representations, for example, memory and its sources (i.e. the SRE), perceptual stages (to facilitate self-relevant processing), associations of the self and objects, attention and decision making, and different brain regions (e.g., Sui, 2016; Sui & Humphreys, 2015). However, this idea has been criticised as the argument was based on results restricted to particular experimental designs and contexts, thus lacking generalisation and not being able to address the role of the self in cognition more generally (Lane, Duncan, Cheng, & Northoff, 2016). On the other hand, researchers have suggested that the self is a special type of attention (e.g., Conway et al., 2016; Turk et al., 2011). The potential special role of the self in cognition has thus clearly not yet been resolved.

## 1.5 Emotion and episodic memory

In addition to the involvement of the self, emotion is another factor that has been shown to facilitate episodic memory (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). Emotion can also enhance the SRE (D'Argembeau, Comblain, et al., 2005; Durbin et al., 2017). Emotion is the complex conscious state of intense pleasure or displeasure involving psychological or physical changes (Cabanac, 2002; Gendron & Barrett, 2009; Myers, 2004; Ochsner & Gross, 2005). In laboratories, emotion is often triggered by presenting emotional pictures (Bisby & Burgess, 2014; Galli, Griffiths, & Otten, 2014; MacKenzie et al., 2015; B. Wang, 2014; Yick et al., 2015) or words (Adelman & Estes, 2013; Padovani, Koenig, Brandeis, & Perrig, 2011; Windmann & Hill, 2014) to the participants. It has been shown that by triggering emotion in psychological experiments, several psychological activities are affected (Gendron, 2010; Izard, 2010), including attention control (Eysenck, Derakshan, Santos, & Calvo, 2007; Ochsner & Gross, 2005; Öhman, Flykt, & Esteves, 2001), decision making (Bechara, 2004; Bechara, Damasio, & Damasio, 2000; Seymour & Dolan, 2008), visual identification (Joffe, 2008; Kitada, Johnsrude, Kochiyama, & Lederman, 2010; Wong, Cronin-Golomb, & Neargarder, 2005) and, most relevant to this thesis, episodic memory (Galli, Wolpe, & Otten, 2011; B. Wang, 2014; Windmann & Hill, 2014; Yick et al., 2015).

Emotion can be differentiated into two dimensions: valence and arousal (Adelman & Estes, 2013; Hamann, 2001). Valence is the direction of emotion, whether it is positive (e.g., happy) or negative (e.g., sad), whereas arousal is the excitement level of the emotion, it can be higher (e.g., surprise) or lower (e.g., calm). There have been studies suggesting that emotional items enhance memory and recollection (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003) regardless of the level of arousal (Kensinger, 2009; Kensinger & Schacter, 2008), while other studies suggested that arousal but not emotion enhances memory (Mather & Sutherland, 2009; Phelps, 2006). Source memory studies also suggest that emotional items facilitate the retrieval of source information relative to neutral items (Doerksen & Shimamura, 2001; Yick et al., 2015). It has been suggested that emotion enhances memory due to the tendency to allocate limited cognitive resources to emotional events because of their relevance to the individuals (Nairne, 2010). However, other studies do not provide evidence that emotional stimuli necessarily boost memory (e.g., Bisby & Burgess, 2014; Cook, Hicks, & Marsh, 2007; MacKenzie et al., 2015). Or, emotion may boost the subjective feeling of remembering but not objective memory accuracy (Sharot, Delgado, & Phelps, 2004).

In the context of the SRE, a few studies have found that positive emotional items predict greater source accuracy for the self versus others (i.e. a source SRE). This pattern was interpreted as people having a preference for keeping a positive self-image, hence enhancing the link between positive adjectives and themselves (D'Argembeau, Comblain, et al., 2005; Durbin et al., 2017). The majority of other SRE studies do not suggest that emotion affects the size of the SRE (Fossati et al., 2004; Gutchess, Kensinger, Yoon, et al., 2007; Pauly, Finkelmeyer, Schneider, & Habel, 2013; Yang, Truong, Fuss, & Bislimovic, 2012). Given these diverse results in the literature, it is not clear how emotion affects different types of memory (i.e. recollection and familiarity) and what its role is in the SRE. This issue of emotion in episodic memory will be investigated as part of this thesis by manipulating emotional valence of the memory materials, to add to the small literature on the effect of emotion on self-referenced memory.

## 1.6 Issues to be addressed in the current thesis

### 1.6.1 Research questions

The sections above review the literature on the SRE. As discussed, the reasons underlying the SRE are unclear due to the diverse results in the literature. In addition, the lack of proper definitions and differentiations between closeness and familiarity have prevented a full understanding of the role of the self in episodic memory. Brain imaging studies of the SRE have focused on the brain activity during memory retrieval, but less work exists on activity during memory encoding. There is also limited electrophysiological evidence regarding the relationship between the self and episodic memory.

Accordingly, the current thesis aimed to address the following two research questions about the role of the self in episodic memory:

1. What is the effect of closeness to others on the SRE?
2. What are the electrophysiological correlates of encoding and retrieving information regarding oneself?

To answer the first question, three behavioural experiments were designed in which familiarity was kept constant, but levels of closeness differed (Experiments 1-3). Subjective ratings of closeness and familiarity to others were acquired before engaging with memory tasks. This procedure allowed a control of any effect of familiarity on the SRE, honing in on possible differences as a function of closeness. To answer the second question, EEG was employed because of its temporal resolution to reveal neural correlates of memory encoding and retrieval. These were addressed by considering ERPs and oscillations (Experiments 4-5).

### 1.6.2 Overview of experiments

Experiment 1 was designed to demonstrate the effect of closeness on the SRE with familiarity controlled for the “other” conditions. Participants encoded trait adjectives by judging them in relation to themselves, a close other or a distant other. Memory performance was tested using a Remember/Know procedure. The SRE was predicted to be present only if familiarity is not exclusively responsible for the superior memory for the self versus others. If, instead, closeness is a key factor in the SRE, memory for trait adjectives processed in relation to a close other should be better than memory for trait adjectives processed in relation to a distant other. Both should be worse than memory for self-referenced adjectives. Experiment 2 investigated the types of information supporting the superior memory for the self by employing an objective source memory paradigm rather than subjective Remember/Know judgments. If source information (i.e. the self, close other or distant other) is used to support memory decisions in Experiment

1, a similar pattern of results would be expected using source memory in Experiment 2. Experiment 3 investigated the contributions of individual differences to the superior memory for the self. Individuals' self-esteem and big-five personality traits (John & Srivastava, 1999; Komarraju, Karau, Schmeck, & Avdic, 2011) were measured for this purpose. If individual differences contribute to the SRE, an interaction between personality ratings and the SRE would be expected. Experiments 4 and 5 investigated the electrophysiological activities during encoding and retrieval of self- and other-pertained information, with the self versus a close other in Experiment 4 and the self versus a distant other in Experiment 5. The primary interest was in how encoding-related and retrieval-related ERP and oscillatory effects differed between the self and another. During encoding, if the self mobilises additional conceptual processes and top-down control than the others, ERP and oscillatory analysis may suggest time- and spatial-dissociable pre- (Fan et al., 2013; Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 1998; Tacikowski & Nowicka, 2010) and post-stimulus (Friedman & Trott, 2000; Hanslmayr & Staudigl, 2014; Hanslmayr, Staudigl, & Fellner, 2012; Otten & Rugg, 2001; Otten, Sveen, & Quayle, 2007; Paller & Wagner, 2002) subsequent memory effects to the self and others. In addition, during retrieval, the self should give rise to larger old/new effects to familiarity (Azimian-Faridani & Wilding, 2006; Curran, 2000; Woodruff et al., 2006) and recollection (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996) and to oscillatory power related to the reinstatement of memory representations (Guderian & Duzel, 2005; Hanslmayr, Staresina, & Bowman, 2016; Hanslmayr & Staudigl, 2014), if the self mobilises more contribution of the memory processes to the memory accuracy compared to others.

# Chapter 2. EEG and episodic memory

EEG is a technique that captures the electrical activity of the brain and has been one of the major techniques in the history of biological research and clinical applications (Fernando Lopes da Silva, 2010; Luck, 2014). The fact that electrical activities of the brain can be measured has been demonstrated for over a century. Early research put electrodes directly into the cerebral hemispheres of animals (e.g., rabbits, dogs or monkey) to observe the electrical activities of the brain (e.g., Brazier, 1984; Caton, 1875). The first demonstration that electrical brain activities are observable on the scalp can be traced back to 1929, when Hans Berger used electrodes placed on the human scalp. After amplification, changes in the electrical activities could be observed and plotted over time (Berger, 1929). To date, scalp-recorded EEG has been one of the main techniques in cognitive neuroscience and psychology to investigate the correlation between neural activity and human behaviour (Luck, 2014).

The intracerebral origin of scalp-recorded EEG is thought to be postsynaptic potentials of pyramidal cells in the cortex, which are aligned perpendicularly to the cortical surface (Fernando Lopes da Silva, 2010; Luck, 2014). These postsynaptic potentials are the result of slow membrane potential changes over time. There are two kinds of postsynaptic potentials - excitatory and inhibitory - which form the basis of EEG signals. In the process of excitatory or inhibitory change, a large number of neurons that are active synchronously and aligned in parallel to each other can generate an open electrical field that is sufficiently large to be observable on the scalp. Action potentials, which reflect a much faster membrane electrical change compared to postsynaptic potentials, are unlikely to contribute to scalp-recorded EEG due to their relatively short-lived and minimal voltage change. In the case of scalp-recorded EEG, it is more likely for electrodes to pick up neuronal activities from nearby brain regions, as the electric fields decay exponentially as the distance increases (Luck, 2014; Rugg & Coles, 1995). The EEG technique has been used widely in cognitive neuroscience and psychology, investigating the correlation between electrical brain activities and human cognition provides additional insights into the mechanisms underlying behaviour.

Below, I introduce the two main approaches in which EEG data are considered: event-related potential (ERP) and oscillatory analyses. These approaches are based on the same type of data but have been found to highlight different aspects of episodic encoding and retrieval (e.g., Hanslmayr et al., 2016; Rugg & Curran, 2007). ERP and oscillatory analyses involve different signal-processing procedures and conceptual assumptions (Pfurtscheller & da Silva, 1999). It has been shown that ERPs and oscillatory activities allow different but correlated functional inferences. For example, during memory retrieval, ERP studies mostly capture different types of retrieval-related processes such as recollection and familiarity (e.g., Rugg & Curran, 2007; Woodruff et al., 2006). On the other hand, oscillatory studies have focused on neural reinstatement during retrieval (e.g., Hanslmayr et al., 2016; Staudigl, Vollmar, Noachtar, & Hanslmayr, 2015). To consider all possible effects of the self on electrical brain activity, both ERPs and oscillations are considered in this thesis.

## 2.1 ERPs

The EEG signal is a mixture of task-relevant and task-irrelevant activities and it is not easy to differentiate between the two given that the relatively small signal-to-noise ratio. Additionally, in most cases, the relevant activities of interests are buried in noise. In order to observe task-relevant activities, segments of the EEG are time-locked to an event of interest, for example, the onset of a stimulus on the screen or the execution of a response. Segments belonging to the same event are then averaged, which reduces the background noise and task-irrelevant activities and retains task-relevant activities (Luck, 2014; Rugg & Coles, 1995). The resulting ERP waveforms consist of a series of positive and negative deflections.

In most cases, differences between conditions are required for meaningful interpretations. Without a baseline condition, it is impossible to know whether an aspect of the ERP waveform specifically relates to an experimental manipulation. For example, observing a positive deflection that deviates from zero at a certain time point in one experimental condition is not necessarily due to that condition. The deflection may occur in all conditions. Only ERP differences of at least two conditions can be linked to the experimental manipulations. A positive deflection in one but not another condition means that the two conditions differ in that aspect of the ERP waveforms, allowing the deflection to be used to understand the cognitive and neural processes that differentiate the conditions.

ERP waveforms can be quantified using a variety of measures, for example a peak or trough or mean amplitude. Waveforms can also be decomposed into their constituent parts given that multiple activities are thought to superimpose and give rise to the waveforms observed on the scalp. Regardless of the measure that is used, the statistical analyses usually focus on the time course, scalp distribution and amplitude of differences between experimental conditions (Johnson Jr, 1992; Luck, 2014; Otten & Rugg, 2005). The time course reflects the time at which a difference occurs, which can be discerned with excellent precision given the high temporal resolution of EEG. This information provides insights into the relative time courses of two events or conditions. Scalp distribution refers to the scattering of activity across electrode locations, indicating where differences in activity are largest and smallest. For example, a difference might be larger at frontal than posterior electrodes. Scalp distributions are considered to reflect the qualitative nature of the underlying cognitive and neural processes (e.g., Otten & Rugg, 2005; Rugg & Curran, 2007; Wilding & Rugg, 1996). The last aspect, amplitude, is the size of the difference that is observed. This is considered to be an index of a quantitative difference between experimental conditions (Luck, 2014; Otten & Rugg, 2005). If ERPs differ in amplitude but not scalp distribution, the same cognitive and neural processes are thought to be evoked in each, but to different degrees.

ERPs have been used to investigate brain activity in relation to various psychological issues, including episodic memory (e.g., D. I. Donaldson & Rugg, 1999; Duzel et al., 1997; Johansson & Mecklinger, 2003; Rugg & Curran, 2007; Woodruff et al., 2006). After introducing EEG oscillations, I will describe the findings of past ERP studies investigating memory encoding, memory retrieval and self-related processing.

## 2.2 Oscillatory activities

In addition to ERPs, oscillations are another approach to analysing EEG data. These analyses take advantage of the fact that EEG data are composed of rhythms of slower and faster frequencies, whose contributions differ in amplitude over time. Oscillatory analyses provide an estimate of the power (amplitude) in specific frequency bands at particular times. This approach has been applied to investigate various topics in cognitive neuroscience and has become influential in recent decades. Oscillatory activities are often described in frequency bands labelled via the Greek alphabet, for example alpha (8-12 Hz), beta (13-30 Hz) and theta (4-7 Hz). Activities in these bands are defined by peak frequency, bandwidth and power (F. L. da Silva, 2013). For example, an alpha power decrease represents a power change at peak frequency of 8-12 Hz with a bandwidth of 4 Hz. Although the frequency boundaries of the bands lack consistent agreements, they have been used widely in communication (e.g., F. L. da Silva, 2013; Herrmann, Grigutsch, & Busch, 2005).

One of the basic assumptions behind the time-frequency transformation is that any given signal can be decomposed into sinusoidal oscillations consisting of different frequencies (Dumermuth, 1977). By applying time-frequency transformations, the information in EEG signals can be transformed from the time into frequency domain, which reveals the power and phase information of certain frequencies across scalp. The time-frequency transformation can be achieved by filtering, Fourier transformation or wavelet transformation (Herrmann et al., 2005). Compared to filtering and Fourier transformation, wavelet transformation is the best approach to investigating oscillations related to cognitive events due to its ability to retain time-course information (Galambos, 1992). Wavelet transformations will therefore be used in this thesis for time-frequency analyses.

Neural oscillations reflect repetitive or rhythmic activities in the central neural system. They represent the repeated variations of a large population of neurons in synchronisation (Buzsaki, 2006), in order to maintain coherent cognition and behavioural outputs (Dehaene, Kerszberg, & Changeux, 1998). Such activities can be observed at various levels of neuronal activities, including single spikes, local field potentials and large scale activities. Large scale activities are one form of oscillations that are able to be picked up by scalp recorded EEG (Hanslmayr et al., 2016). Oscillations are described by their amplitude and phase, where amplitude is the strength of the oscillations and phase the point in the cyclic activity (from 0 to 2pi) (Herrmann et al., 2005; Roach & Mathalon, 2008). There are three types of oscillations that can be measured using EEG: spontaneous, evoked and induced oscillations (Galambos, 1992; Herrmann et al., 2005). These types of oscillations can be differentiated by their degrees of phase-locking to specific events. Spontaneous oscillations are uncorrelated with cognitive events. Induced oscillations are correlated with, but not phase-locked to, cognitive events, and evoked oscillations are correlated and phase-locked to events. Evoked activity can be measured by averaging EEG segments across trials in a specific condition before transforming the signal into the frequency-domain. In this case, spontaneous and non-phased locked information are cancelled out and leave only the phase-locked information. Induced activity can be accessed by applying time-frequency transformation before averaging trials. This retains phase-locked and non-phase-locked information and transforms both into the frequency-domain. Averaging increases the signal-to-noise ratio and provides the basis for statistical comparisons between conditions (Bastiaansen, Oostenveld, Jensen, & Hagoort, 2008; Herrmann et al., 2005). The current thesis considers induced activity as it can provide non-phase-locked information on top of phased-locked ERPs.

Studies that focus on phase and power changes have suggested that oscillatory activities are correlated to various aspects of human cognition (da Silva, 2013; Düzel, Penny, & Burgess, 2010; Hanslmayr et al., 2016; Herrmann et al., 2005; Waldhauser, Bauml, & Hanslmayr, 2015; Ward, 2003). In the following sections, I will summarise oscillatory findings relevant to episodic memory encoding and retrieval.

## 2.3 Encoding-related activity

Research investigating brain activities related to memory encoding typically use the subsequent memory or Dm (difference due to memory, dm effect; Paller & Wagner, 2002) approach. In this approach, brain activity in response to individual events is recorded during encoding and categorised according to memory accuracy during a subsequent memory test. Activity that differentiates events that are later remembered versus forgotten is thought to play a role in successful encoding. The subsequent memory approach has been used to identify encoding-related activity before (pre-stimulus) and after (post-stimulus) the to-be-encoded event.

### 2.3.1 Post-stimulus encoding activities

#### 2.3.1.1 ERPs

It has been shown that brain activity during encoding is able to predict whether an item will be remembered or forgotten in a later memory test (Friedman & Johnson, 2000; Paller & Wagner, 2002). ERP studies using the subsequent memory approach have demonstrated positive, slow deflections for subsequently remembered items between 400 ms until 800 ms or later after item onset, with a maximal difference at frontal (Friedman & Trott, 2000; Otten & Rugg, 2001; Otten et al., 2007; Paller & Wagner, 2002) or parietal (Paller, Kutas, & Mayes, 1987; Sanquist, Rohrbaugh, Syndulko, & Lindsley, 1980) scalp sites. These subsequent memory effects (SMEs) have been considered to be a neural correlate of memory encoding due to their sensitivity to later memory accuracy (Paller et al., 1987; Paller & Wagner, 2002). The time course and scalp distributions of SMEs vary with types of encoding task, types of stimulus material and properties of the memory task. It has been suggested that distinct encoding processes are represented in different SMEs (Yick et al., 2015). Frontally-distributed SMEs starting around 400 ms after stimulus onset have been linked to the processing of semantic (meaning-related) information (Friedman & Trott, 2000; Otten & Rugg, 2001; Otten et al., 2007; Paller & Wagner, 2002). More posteriorly-distributed SMEs starting at around the same time have been interpreted as reflecting the engagement and maintenance of visual information in working memory (Otten et al., 2007). SMEs with earlier onsets have been linked to attentional and perceptual processes that facilitate memory encoding (Duarte, Ranganath, Winward, Hayward, & Knight, 2004; Otten et al., 2007), while SMEs with later onsets may reflect sustained attentional and cognitive control processes in working memory (Caplan, Glaholt, & McIntosh, 2009; A. S. N. Kim, Vallesi, Picton, & Tulving, 2009; Otten & Rugg, 2001).

Early ERP studies showing SMEs recorded from only a few electrodes (Paller et al., 1987; Sanquist et al., 1980), restricting a precise analysis of the scalp distribution of the effects (Friedman & Johnson, 2000). Later studies used high-density recordings and current source density analyses to estimate the signal sources in the brain. These studies suggest that the positive SME is related to a dipole in the left inferior prefrontal cortex (Friedman & Johnson, 2000; Friedman & Trott, 2000). Despite the fact that it is not possible to directly link ERPs to certain anatomical regions due to the inverse problem, this observation is in line with more recent studies using functional imaging techniques. For items that are subsequently remembered, increased activity was found in certain areas, including prefrontal cortex (Paller & Wagner, 2002), hippocampus (Fell et al., 2011; Guderian, Schott, Richardson-Klavehn, & Duzel, 2009; Park & Rugg, 2010) and posterior parietal cortex (Andersen, Essick, & Siegel, 1985; R. Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Uncapher & Wagner, 2009). Intracranial recordings and neuropsychological studies also suggest a contribution of MTL structures to encoding, in particular the hippocampus (Fernandez et al., 1999; Guillem, Rougier, & Claverie, 1999; Knight & Nakada, 1998). These findings suggest that the subsequent memory approach is a useful method to investigate the brain activities associated with successful memory encoding.

Studies have shown that the SME depends on various factors, indicating that memory encoding is supported by multiple and task-specific neural systems. For example, studies comparing encoding-related activities supporting later recollection and familiarity have found SMEs with different scalp distributions. This points to qualitative differences between the two conditions (Duarte et al., 2004). In addition, it has been shown that the SME depends on depth of encoding (Craik & Lockhart, 1972; Craik & Tulving, 1975): its polarity changes from positive to negative when the encoding task requires shallower (e.g., alphabetic judgments) as opposed to deeper (e.g., semantic judgments) encoding. The polarity difference again indicates a qualitative, instead of quantitative, difference (Otten & Rugg, 2001). Functional imaging studies have revealed that a subset of all encoding-related brain regions is sensitive to depth of processing, namely the left anterior hippocampus and left ventral inferior frontal gyrus but not left posterior hippocampus and right inferior frontal cortex. This indicates that encoding is supported by different subsets of neurons with different functional sensitivities (Otten et al., 2001).

To summarise, ERP activity is able to predict whether an item will be recognised in a later memory test. However, such activity is affected by various factors, which affect its time course and scalp distribution. These properties suggest that multiple and functionally specialised neuronal populations contribute to encoding-related effects seen in ERPs. Functional imaging studies using the SME approach suggest that the hippocampus and prefrontal cortex are involved in memory formation. These SMEs provide additional qualitative information that cannot be revealed by behavioural responses alone.

To my knowledge, there have been no prior studies investigating encoding-related ERP activities for self-referenced information. It will be a great contribution to the literature to reveal how brain activity associated with the processing of self-referenced information affects encoding.

#### 2.3.1.2 Oscillatory activities

In addition to ERP studies, there have been studies investigating the relationship between brain oscillations and memory encoding. It has been shown that successful memory encoding is related to power changes in a range of lower frequencies. Power has been shown to decrease in theta (4-7 Hz), alpha (8-12 Hz) and beta (13-30 Hz) bands following items that were subsequently remembered versus forgotten (Burke et al., 2014; Fellner, Bauml, & Hanslmayr, 2013; Greenberg, Burke, Haque, Kahana, & Zaghloul, 2015; Hanslmayr et al., 2016; Hanslmayr et al., 2011; Long, Burke, & Kahana, 2014; Noh, Herzmann, Curran, & de Sa, 2014). The power decreases in alpha and beta bands were focused on left prefrontal regions for verbal materials (Hanslmayr et al., 2011) and parietal-occipital regions for pictorial materials (Noh et al., 2014). This observation has been related to the degree of perceptual and conceptual processing in relevant cortical structures (Jensen & Mazaheri, 2010; Klimesch, 2012), which affects the ability of later memory retrieval (Hanslmayr et al., 2016).

Interestingly, not only power decreases, but also power increases, have been correlated with episodic memory formation. These increases occur in the same frequency bands as mentioned above (e.g., Hanslmayr et al., 2011; B. C. Lega, Jacobs, & Kahana, 2012; Meeuwissen, Takashima, Fernandez, & Jensen, 2011; Staudigl & Hanslmayr, 2013). In order to deal with the diverse findings, there have been proposals that oscillatory SMEs depend on task-specific processes (e.g., levels of processing, Craik, 2002; Craik & Lockhart, 1972) and type of memory test (Hanslmayr & Staudigl, 2014), similar to what has been suggested for SMEs seen in ERPs. For example, decreases in alpha and beta power have been observed during semantic (i.e. deeper) but not non-semantic (i.e. shallower) encoding tasks, whereas increases in theta power occur during non-semantic but not semantic encoding (Fellner et al., 2013; Hanslmayr, Spitzer, & Bauml, 2009). These findings suggest that successful memory formation relies on processing appropriate perceptual or conceptual aspects of the materials (e.g., Hanslmayr & Staudigl, 2014; Hanslmayr et al., 2012).

To briefly summarise, brain oscillations during memory formation have not yet been widely investigated. How brain oscillations change as a function of successful encoding also lacks agreement across studies. Nevertheless, findings have emerged that alpha and beta power decreases and theta power increases as a function of successful memory formation. These power changes may reflect the processing of perceptual and conceptual properties of the memory materials. To date, there have been no studies investigating brain oscillations during self-referenced memory formation, leaving the interaction between the self and encoding-related oscillatory activity unknown. This issue will be addressed in this thesis.

### 2.3.2 Pre-stimulus brain activity

In addition to demonstrating encoding-related brain activities after stimulus onset, researchers have extended their interest to brain activities before stimulus onset. These studies have shown that brain activity leading up to a cognitive event can affect encoding success, and that such pre-stimulus activity is dissociable from encoding-related activities after the event (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006; Addante et al., 2011; M. J. Gruber & Otten, 2010; Mackiewicz, Sarinopoulos, Cleven, & Nitschke, 2006; Park & Rugg, 2010; Salari & Rose, 2016). Pre-stimulus activity is usually assessed via the subsequent memory procedure and a cue presented before the onset of the memory material. Various cognitive functions have been linked to encoding-related brain activities found during pre-stimulus intervals, for example voluntary control (Adcock et al., 2006; M. J. Gruber & Otten, 2010; M. J. Gruber, Watrous, Ekstrom, Ranganath, & Otten, 2013), semantic preparation (Otten, Quayle, Akram, Ditewig, & Rugg, 2006; Otten et al., 2010), resource availability (Galli, Gebert, & Otten, 2013) and emotion (Galli et al., 2014; Galli et al., 2011; Mackiewicz et al., 2006; Yick, Buratto, & Schaefer, 2016). Below I summarise relevant findings in the ERP and oscillatory literature.

#### 2.3.2.1 ERPs

It has been shown that ERPs before an event can predict whether it will be remembered or forgotten in a later memory test (Galli et al., 2013; M. J. Gruber & Otten, 2010; Yick et al., 2016). For items that are subsequently remembered, more positive-going (e.g., Galli et al., 2014; Galli et al., 2011; M. J. Gruber & Otten, 2010; Yick et al., 2016) or negative-going (e.g., Otten et al., 2006; Otten et al., 2010; Padovani et al., 2011) deflections are observed during the pre-stimulus interval compared to items that are subsequently forgotten. This effect has been denoted as ‘pre-stimulus activity’ (M. J. Gruber et al.,

2013) or the 'pre-stimulus Dm effect[1]' (Yick et al., 2016), in line with functional imaging studies investigating brain activities during a pre-stimulus interval (Park & Rugg, 2010). However, the functional significance of pre-stimulus activity is relatively unclear to date. Studies have attempted to relate pre-stimulus activity to memory formation, but inconsistency in the findings preclude a clear explanation of the activity. For example, Yick et al. (2016) found a left-frontal positive pre-stimulus SME around 300 ms before the onset of negative but not neutral pictures. This effect was proposed to be the result of more processing resources being mobilised to process negative items that are subsequently remembered. This interpretation is similar to an earlier study by Galli et al. (2013), which suggested that the pre-stimulus SME is sensitive to the degree to which processing resources are available before stimulus onset. However, the effect found in Galli et al. (2013) was negative-going, as opposed to the positive-going effect seen in Yick et al. (2016) at similar sites. Interestingly, in another series of studies, a wide-spread positive pre-stimulus SME was sensitive to emotional regulation mechanisms in women. When emotional regulation was engaged during encoding, the pre-stimulus SME was absent (Galli et al., 2014). This helped explaining the findings in Galli et al. (2011), in which a right positive pre-stimulus SME was evident for negative pictures in women but not men. These findings were interpreted via different emotional regulation strategies adopted by women and men. A similar wide-spread positive-going pre-stimulus SME was found in a study that manipulated subjective motivation and voluntary control over encoding preparation rather than emotion regulation (M. J. Gruber & Otten, 2010). This suggests that a common mechanism may aid encoding in these circumstances. In addition to these accounts, a frontal negative pre-stimulus SME has been interpreted as an adaptive preparatory process that aids semantic and elaborative encoding of an upcoming event, due to the frontal effect only being present in semantic encoding tasks (Galli, Choy, & Otten, 2012; Otten et al., 2006; Otten et al., 2010; Padovani et al., 2011).

It is clear that the findings and interpretations of the pre-stimulus SME have been diverse. Nevertheless, some consistency in the patterns of results shed light on the link between pre-stimulus activity and memory formation. For instance, negative ERP modulations during a pre-stimulus interval may reflect the preparation for semantic decisions about an upcoming event (Galli et al., 2012; Otten et al., 2006; Otten et al., 2010). On the other hand, positive modulations during a pre-stimulus interval may reflect emotional regulation (Galli et al., 2014; Galli et al., 2011) or attentional recourse allocation that is under voluntary control (M. J. Gruber & Otten, 2010; Yick et al., 2016).

To date, there have been no studies that have considered pre-stimulus activities in relation to self-referential episodic encoding. It is thus unknown whether participants

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[1] This effect is referred as 'pre-stimulus subsequent memory effect' or 'pre-stimulus SME' in this thesis for communication.

adopt different anticipatory or preparatory processes depending on the degree of closeness between the self and others, for example to narrow the search for information pertaining to a particular person in an upcoming trait judgment.

#### 2.3.2.2 Oscillatory activities

Similar to the limited studies on pre-stimulus SMEs in ERPs, few studies have addressed whether brain oscillations before an event can predict whether the event will be remembered or forgotten during a later memory test (Fell et al., 2011; M. J. Gruber et al., 2013; Guderian et al., 2009; Merkow, Burke, Stein, & Kahana, 2014; Salari & Rose, 2016). Across these studies, theta power increases have consistently been found during intervals before items that are subsequently remembered. This pattern has been found with diverse experimental conditions. For example, it has been shown that pre-stimulus frontal theta oscillations are related to monetary rewards and successful memory formation. In a high reward condition, an increase in frontal theta power around 1000 to 500 ms before word onset correlated with later memory of the word (M. J. Gruber et al., 2013). This frontal theta modulation was interpreted as resulting from dopaminergic activity related to reward anticipation. A similar frontal theta power increase was observed around 200 ms before stimulus onset in a study using MEG to localise the source (Guderian et al., 2009). The increase originated from regions within the MTL, including the hippocampus, regardless of levels of processing. The theta increase was thought to reflect a task-independent brain state that improves later encoding. The observation that the theta oscillations originated from the MTL was later enforced by intracranial studies (Fell et al., 2011; Merkow et al., 2014). Intracranial electrophysiological recordings on hippocampus of epilepsy patients suggested similar patterns of theta oscillations with the theta oscillations observed on the scalp (Fell et al., 2011; Merkow et al., 2014). These studies argued that pre-stimulus theta oscillations are closely linked to inhibitory top-down control processes (Fell et al., 2011) and related to item but not associative memory (Merkow et al., 2014). In a more recent study, increases in frontal theta power around 900 to 700 ms before stimulus onset have been related to maintaining information in working memory (Khader, Jost, Ranganath, & Rosler, 2010) while preparing for an upcoming event (Salari & Rose, 2016).

In addition to theta band oscillations, there have been two studies suggesting that encoding-related activity emerges in other frequency bands. Fell et al. (2011) found pre-stimulus increases in alpha power in the MTL around 1000 to 500 ms before the onset of items that were subsequently remembered. These increases were considered to be possibly related to inhibitory top-down control processes. On the other hand, Salari and Rose (2016) found that beta power increased around 900 to 0 ms before stimulus onset, reflecting an optimal neural state to facilitate memory formation. It is not clear why there are only two reports in the literature of encoding-related activity apart from theta oscillations. One reason might be that pre-stimulus oscillations are a relative new area of research, and insufficient prior studies exist for researchers to make predictions about frequency bands other than theta. More exploratory investigations will help understand this issue.

It seems that functional interpretations of pre-stimulus brain oscillations are typically not directly linked to memory encoding, for example, reward (M. J. Gruber et al., 2013), state-related adaptation (Guderian et al., 2009), inhibition control (Fell et al., 2011), and working memory (Salari & Rose, 2016). This may suggest that SMEs seen in oscillatory activity before stimulus onset differ from those seen in ERPs. Given the limited number of studies investigating the role of oscillatory activity in episodic memory, this issue will be addressed in the current thesis. In addition, similar to ERP pre-stimulus SMEs, there is a paucity of work that compares anticipatory processes for judgments about different people (e.g., the self or a close other).

## 2.4 Retrieval-related activity

In addition to brain activities during memory encoding, studies have investigated brain activities during memory retrieval. Retrieval-related brain activities are usually investigated via ‘old/new effects’ (Rugg & Curran, 2007). These effects contrast brain activities elicited by correctly recognised old items with those elicited by correctly rejected new items. Out of the four response categories in a recognition memory test (hits, misses, false alarms and correct rejections, see Section 1.1.1), the comparisons usually contrast hits and correct rejections (e.g., Hayama, Johnson, & Rugg, 2008; Rugg & Curran, 2007; Yonelinas, Otten, Shaw, & Rugg, 2005). Old/new effects have been useful for isolating electrophysiological activities and brain regions that contribute to successful memory retrieval. Below, I summarise relevant ERP and oscillatory findings related to episodic retrieval.

### 2.4.1 ERPs

Various ERP old/new effects have been observed and associated with different aspects of the retrieval process. Two of the main retrieval effects are the ‘left-parietal effect’ and the ‘mid-frontal effect’, which are functionally dissociable (Rugg & Curran, 2007; Vilberg & Rugg, 2007) and respectively related to recollection and familiarity in the context of dual-process accounts of episodic memory (Yonelinas, 1994; Yonelinas et al., 2010). The left-parietal effect is a positive-going effect that is largest over left parietal scalp sites between around 500-800 ms and sensitive to factors affecting recollection, such as source memory (Senkfor & Van Petten, 1998; Wilding & Rugg, 1996) and remember responses (Curran, 2004; Duzel et al., 1997). In contrast, the mid-frontal effect is a frontally-distributed positive-going effect around 300-500 ms after a retrieval cue and sensitive to factors affecting familiarity, for example confidence level of decisions (Woodruff et al., 2006), false decisions for foils that are similar to studied items (Curran, 2000) and the placements of response criteria (Azimian-Faridani & Wilding, 2006). These two old/new effects have been frequently involved in the studies of episodic memory retrieval (e.g., Curran, 2000; Duzel et al., 1997; Rugg & Curran, 2007; Wilding & Rugg, 1996; Yick & Wilding, 2008).

The two old/new effects were first differentiated by Duzel et al. (1997), who correlated scalp-recorded brain potentials with autonoetic and noetic awareness using the Remember/Know procedure. The results suggested two temporally and spatially dissociable old/new effects: an early positive frontal old/new effect associated with know judgments and a later positive posterior old/new effect associated with remember judgments. Many studies have since investigated the functional dissociations of the mid-frontal and left-parietal effects (e.g., Azimian-Faridani & Wilding, 2006; Rugg & Curran, 2007; Woodruff et al., 2006). For example, it has been shown that the mid-frontal but not left-parietal effect is sensitive to increments in familiarity due to falsely recognising new items that are similar to old ones. The left-parietal effect is only evident for correctly recognised old items (Curran, 2000). Studies comparing memory decisions with gradient criterion placements also indicate that the magnitude of the mid-frontal effect varies as a function of familiarity strength, while the left-parietal effect remains unaltered (Wang, de Chastelaine, Minton, & Rugg, 2012; Woodruff et al., 2006). It has been shown that the left-parietal effect is also independent of response confidence level to unstudied items and stimulus probability (Curran, 2004; Curran & Hancock, 2007; Herron, Henson, & Rugg, 2004; Woodruff et al., 2006). These findings have established firm links between the left-parietal effect and recollection on the one hand and the mid-frontal effect and familiarity on the other.

It is worth noting that alternative explanations of the old/new effects argue that recollection is a continuous, instead of discrete, process (e.g., Wixted, 2007). From this perspective, familiarity and recollection act as signal-detection signals on a continuous dimension, where both processes can simultaneously contribute to the overall memory strength. The variations of the mid-frontal effect with familiarity strength can be explained by the argument that the mid-frontal effect represents overall memory strength, instead of pure familiarity. Or, the left-parietal effect for recollected items can be affected by high confidence memory strength, instead of recollection. However, a uniform perspective is not compatible with the functionally dissociable topographies and time-windows of the mid-frontal and left-parietal effects (e.g., Woodruff et al., 2006). The perspective is not able to explain why the two effects are exclusively sensitive to either recollection or familiarity and not both (Rugg & Curran, 2007).

A competing interpretation for the mid-frontal old/new effect is that it reflects conceptual priming due to stimulus repetition, rather than familiarity (the 'FN400'; Voss, Lucas, & Paller, 2010; Voss, Schendan, & Paller, 2010). However, this interpretation has been disputed by studies that indicate that the topography of the mid-frontal effect differs from that of the conceptual priming effect (Bridger, Bader, Kriukova, Unger, & Mecklinger, 2012; Rugg & Curran, 2007; Rugg et al., 1998). The mid-frontal old/new effect also remains intact with manipulations that are known to disrupt conceptual priming (Curran & Cleary, 2003; Ecker, Zimmer, & Groh-Bordin, 2007). Interestingly, recent studies found complex results indicating that the mid-frontal effect is sensitive to both conceptual priming and familiarity (Leynes, Bruett, Krizan, & Veloso, 2017; Strozak, Abedzadeh, & Curran, 2016). One implication from these studies is that no matter what functional process is reflected by the mid-frontal effect, the effect is likely not process pure (Paller, Voss, & Boehm, 2007; Rugg & Curran, 2007). It is unavoidable to repeat stimuli between the study and test phases in a recognition memory test and effects of conceptual priming are accordingly expected to be observed (Rugg & Curran, 2007). Even though the bulk of findings suggest an association between the mid-frontal effect and familiarity, there remains an active debate as to whether the effect also reflects implicit memory or conceptual priming.

In additional to the left-parietal and mid-frontal effects, there are other old/new effects. These attract less attention in the literature but might be useful to the current thesis given their proposed functional significance. For example, a late posterior negativity (the 'LPN'; Herron, 2007; Johansson & Mecklinger, 2003) has been observed to differentiate hits and correct rejections. The early part of this negativity (between 600-1200 ms) may be related to a top-down search for information in memory. A later part of the LPN (between 1200-1900 ms) may instead reflect the maintenance of information that is retrieved. Herron (2007) addressed the functional significance of the LPN by varying task fluency and response fluency independently. The task fluency was assumed to increase as the blocks continuing, while the response fluency was reduced in the middle of the experiment by reversing the responses assigned. It was found that the early LPN is related to task fluency but not response fluency and may therefore index the search for episodic information in cortical regions where items were initially processed at study. Importantly, the early LPN was attenuated across blocks and may reflect that the neural pathways of the effect become more fluent and effortless due to practice (Halder et al., 2005; Reinke, He, Wang, & Alain, 2003). In contrast, the late LPN is not sensitive to task fluency, response fluency or practice and may reflect the maintenance of a retrieved episode. However, it was noted that the LPN might be functionally heterogeneous with subcomponents related to the maintenance of a retrieved episode, retrieval fluency or response monitoring (Herron, 2007).

To the best of my knowledge, there has been only one study investigating the ERPs during memory retrieval of self-referenced episodes (Dulas et al., 2011). Participants incidentally encoded concrete objects with either self-referential (is it pleasant?) or self-external (is it common?) tasks. In a later source memory test, participants were instructed to decide which of the presented pictures had been studied and if so, which encoding task had been completed. The results suggested superior source memory for the self-referential condition and, importantly, significant old/new effects for source correct items in the time windows of the mid-frontal and left-parietal effects, regardless of encoding condition. However, the authors used old/new effects as a tool to address issues related to ageing, instead of the role of the self in episodic memory. They hence did not provide further discussion in the context of episodic memory. One of the aims of the current thesis was to investigate the relationship between the self and episodic memory. The mid-frontal effect, left-parietal effect and LPN are capable of providing information about the degree to which processes related to familiarity, recollection, memory search and information maintenance are engaged. This can be useful to understand the mechanisms of retrieving self- and other-referenced information.

### 2.4.2 Oscillatory activities

Along with ERP old/new effects, brain oscillations during memory retrieval have also been used to investigate the mechanisms of memory retrieval. As for ERP old/new effects, oscillatory activity related to successful retrieval is identified by contrasting activity elicited by correctly recognised studied items (hits) with activity elicited by correctly rejected unstudied items (correct rejections). Successful retrieval has been associated with brain oscillations in various frequency bands, including power increases in theta power (T. Gruber, Tsivilis, Giabbiconi, & Muller, 2008; Guderian & Duzel, 2005), and decreases in alpha (Waldhauser, Johansson, & Hanslmayr, 2012) and beta (Duzel et al., 2003; Khader & Rosler, 2011; Nyhus, 2017). The different frequency bands are thought to capture neuronal populations that serve different roles during retrieval (Hanslmayr et al., 2016). In source memory studies, it has been shown that frontal theta power increases between 300 and 700 ms (Guderian & Duzel, 2005) and 600 and 1200 ms (T. Gruber et al., 2008) are related to successful source retrieval and recollection. Further studies suggest that these theta oscillations are related to transient interactions between cortical regions and the hippocampus for top-down control and reinstating memory-related activations (Guderian & Duzel, 2005; Nyhus & Curran, 2010). In addition, scalp-recorded theta oscillations have been considered in conjunction with functional imaging studies (Polyn, Natu, Cohen, & Norman, 2005; Ranganath, 2010; Summerfield & Mangels, 2005), showing that hippocampal theta oscillations track relations among memory items and their context. Information that is stored in distributed cortical regions can be bound together by the hippocampus to restore the episode (Guderian & Duzel, 2005; Hanslmayr et al., 2016; Hanslmayr & Staudigl, 2014).

Alpha and beta power decreases have been associated with top-down control during memory retrieval. For example, the power decrease in the alpha band has been related to functional inhibition of task-irrelevant neuronal populations in order to maintain optimal performance output (Waldhauser et al., 2012). It was found that alpha power decreases were observed when memory was successfully retrieved while a competing one was successfully inhibited. This interpretation is consistent with the idea that power decreases in the alpha band during working memory tasks reflect top-down inhibitory control over irrelevant information (gating by inhibition; Jensen & Mazaheri, 2010; Klimesch, 2012). Similar interpretations have been offered for beta power decreases. Such decreases have been linked to the suppression of irrelevant information during memory retrieval (Hanslmayr et al., 2012; Khader & Rosler, 2011; Nyhus, 2017; Waldhauser, Bauml, & Hanslmayr, 2015; Waldhauser et al., 2012). In a particular case in which EEG was combined with fMRI (Nyhus, 2017), it was found that posterior beta power decreases for correctly recognised old items were correlated with greater activations in the right frontal cortex and frontal-parietal network (Anderson & Hanslmayr, 2014; Butler & James, 2010). These correlations were most prominent under conditions requiring more cognitive control (e.g., decisions with incorrect source; Nyhus, 2017), suggesting that they are related to memory suppression to inhibit irrelevant details during memory retrieval.

With these findings of brain oscillations in mind, the next question of interest is what the relationship is between oscillatory power changes during memory encoding and retrieval. This issue underlies the cortical reinstatement principle, in which encoding-related activity is restored during a memory test to allow retrieval. The scalp distributions of retrieval-related power decreases have been found to differ depending on the characteristics of the materials (Jafarpour, Fuentemilla, Horner, Penny, & Duzel, 2014; Khader & Rosler, 2011; Staudigl et al., 2015). Such power decreases are thought to reflect material-specific memory reactivation (Hanslmayr et al., 2016). This view is in line with the encoding specificity principle (Morris, Bransford, & Franks, 1977; Tulving & Thomson, 1973), which suggests that the greater the overlap between encoding and retrieval, the more likely is that a memory is reinstated during test. Early fMRI studies also show that brain activities during memory retrieval involve reactivations of the regions involved in memory encoding (Johnson, McDuff, Rugg, & Norman, 2009; Wheeler, Petersen, & Buckner, 2000). These findings of reinstatement during retrieval have been corroborated by studies using EEG and MEG, in which alpha and beta power changes showed similar reinstatements triggered by retrieval cues (Hanslmayr & Staudigl, 2014).

To summarise, brain oscillations during memory retrieval have been associated with top-down control processes aiding correct item recognition and, importantly, processes that coordinate the reinstatement of memory representations in cortical regions where the material was originally encoded. These findings prove that oscillatory activity adds considerable knowledge to what old/new effects in ERPs can provide. To date, there has been only one study on the retrieval of self-referenced information, suggesting it is associated with a left-frontal theta power increase (Mu & Han, 2010). It is not clear whether retrieving self-referenced information shares the same mechanisms as retrieving non-self-referenced information. This question will be part of this thesis.

## 2.5 Electrophysiological findings relevant to self-referencing

In addition to brain activities related to episodic memory, studies have shown that perceiving self-relevant information (e.g., one’s own name) elicits larger amplitudes of ERP components such as the P3 than other types of stimuli. Such demonstrations may be the result of self-relevant stimuli mobilising additional top-down control and attention processes (Fan et al., 2013; Ninomiya et al., 1998; Tacikowski & Nowicka, 2010). However, the tasks used in these studies (e.g., identify one’s own name/face in a series of presentation) did not involve a ‘referencing’ process that binds encoded information to a person. Following this rationale, only studies using self-referencing tasks are considered in the summary below. To the best of my knowledge, there have been only two studies (Fan et al., 2016; Mu & Han, 2013) that have investigated electrophysiological activities during self-referencing.

In an ERP study investigating the relationship between self-esteem and self-referencing of emotional stimuli (Zhang, Guan, Qi, & Yang, 2013), participants were instructed to judge the relevance of positive and negative trait adjectives in relation to themselves. A self-esteem questionnaire followed at the end of the experiment. It was predicted that participants with low self-esteem would demonstrate a positive bias that favours positive traits more than negative traits, due to the preference of having a positive self-image. The results supported this prediction and further suggested that ERP components related to attention (N1 and P2) and a later ERP effect (LPC) were modulated by whether the positive traits were rated as self-relevant. The authors interpreted these results as suggesting that self-referencing can be influenced by personality traits during early attentional processing. In this particular study, only the self condition was included, therefore the difference between self- and other-referencing could not be considered. Mu and Han (2013) investigated the brain oscillations related to self-referencing by instructing participants via a cue to judge whether an upcoming trait adjective was consistent with the characteristics of themselves or a friend. Their results revealed power increases in theta and alpha bands during the period in between cues and traits only for self-referential processing. Power decreases were found in beta and gamma bands, again only during self-referential processing. The authors interpreted the findings in terms of self-related attentional orienting and self-related evaluations, which are supported by neural mechanisms that are distinct from those supporting decisions about other people. However, the authors used the words ‘self’ and ‘a friend’s name’ as cues for the upcoming trait adjective. It is possible that any difference revealed between the self and the other conditions might be contaminated by the perceptual differences of the cues, instead of purely reflecting the difference between the orientation for the self and others.

To summarise, based on the limited findings in the self-referencing literature of electrophysiological activities, it seems that the self can affect attentional control not only during the referencing process itself, but also during the orientation beforehand. However, with so few existing studies, it is impossible to know what brain activities are associated with self-referencing. Further work is thus urgently needed, and this thesis provides more evidence towards the issues mentioned above.

## 2.6 Summary and research interests

In this chapter, the importance of using EEG to address issues related to episodic memory and self-referencing has been highlighted. EEG can provide additional information about the processes underlying various stages of self-reference memory, including anticipation, encoding and retrieval. More specifically, one of the research questions of the current thesis is to investigate the SRE by contrasting electrophysiological activities during encoding and retrieval of information referenced to oneself as opposed to others. This will benefit knowledge about the interaction between the self and episodic memory and provide more insights into the possible processes underlying the SRE. Differences in ERPs and oscillatory activities between the self and a close other are investigated in Experiment 4, and those between the self and a distant other in Experiment 5.

# Chapter 3. Experiment 1: behavioural self-reference effect for the self, a close other and a distant other

## 3.1 Introduction

Experiment 1 was designed to address the first research question of the thesis: What is the effect of closeness to others on the SRE? To address this question, Experiment 1 keeps familiarity to others constant, a factor that has not been properly controlled for in the literature of the SRE (e.g., Symons & Johnson, 1997). Participants were first asked to come up with six names of people they felt close to and then rated their familiarity with, and closeness to, each person. The person closest to a participant was used as their own close other. This close other was compared with the self and a familiar but distant other during encoding and retrieval tasks involving trait adjectives. Following definitions in the literature (Aron et al., 1992; Berscheid et al., 1989; Gachter et al., 2015; Sternberg, 1997), closeness reflects the degree of emotional attachment to another person. This contrasts with familiarity, which reflects the amount of knowledge about another person. The distant other was randomly selected from a list of four fictional characters who participants indicated being sufficiently familiar with.

Using this procedure, the close other can be as close and familiar as possible to the self for each participant, with the distant other also being familiar but less close. This design is intended to compare the self with another individual who is as close as possible to oneself. Familiarity was intended to be kept relatively constant across conditions (see Figure 3.1). The key question of interest was whether a memory advantage would still be observed when judgments about the self are compared with judgments about someone else who approximates the same level of closeness. This comparison directly addresses whether a key factor underlying the SRE is closeness to others or is instead due to the self being special. If closeness to others is not a key factor in the SRE, a prominent SRE should persist when the close other is compared to the self in this design. The distant other condition was designed to have a lower level of closeness but comparable level of familiarity compared to both the self and close other. If closeness to other is a key factor of the SRE, the memory of the distant other condition will be lower than both the self and the close other condition. The memory of the distant other condition will be comparable only when familiarity is exclusively responsible for the SRE.

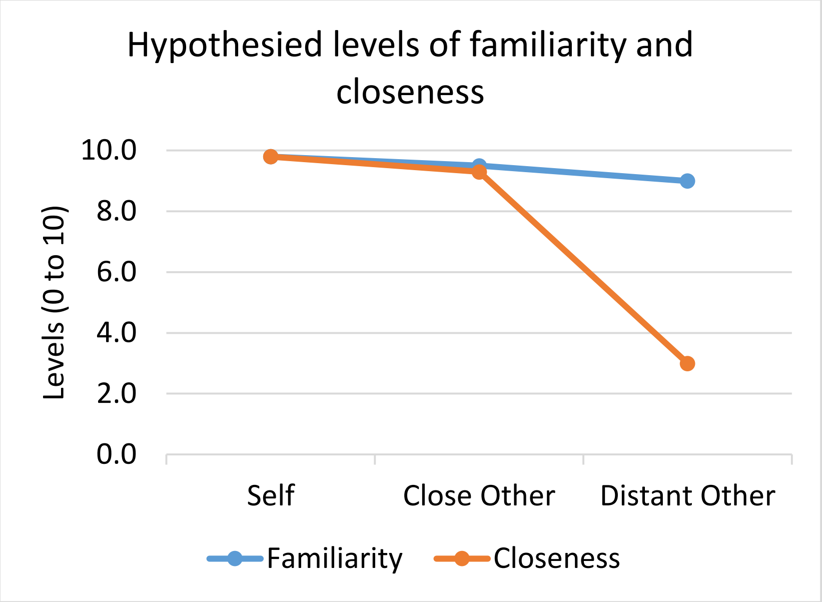

*Figure 3.1. The hypothesized levels of familiarity and closeness of the self, a close other and a distant other in this experiment.*

Past SRE studies that have compared the self with close others (Keenan & Baillet, 1980; Maki & McCaul, 1985) have demonstrated robust SREs. However, because these studies conflated closeness and familiarity, it is not clear which factor drove the SREs. This issue is resolved in the present experiment, which thus provides a better basis for investigating the effect of closeness. Given that familiarity and closeness were equivalent between the self and a close other, any difference found between them must be due to other factors, such as the sense of the self or the sense of agency (Decety & Sommerville, 2003; Klein, 2012). The distant other condition provides a control for the SRE. It was predicted that the difference in memory accuracy between the self and a distant other should be larger than the difference between the self and a close other given that the level of closeness is lower in the former case (Czienskowski & Giljohann, 2002; Klein, 2012; Maki & McCaul, 1985; Symons & Johnson, 1997).

It was also predicted that any memory-related difference would primarily reveal itself in recollection (Conway & Dewhurst, 1995; Leshikar et al., 2015). This prediction is addressed by using the Remember/Know procedure (Tulving, 1985) during the memory test, in which participants give their subjective responses as to whether memory decisions are based on recollection or familiarity. Shorter reaction times were expected for items processed in relation to the self compared to both the close other and distant other conditions if a truly close other does not facilitate information processing as the self (e.g., Sui & Humphreys, 2015).

Another dimension that was manipulated in the present study was the emotional valence of the trait adjectives. Emotion-wise, it has been shown that participants have a tendency to rate positive trait adjectives more self-relevant than negative trait adjectives (Zhang et al., 2013), in order to maintain a positive self-image. There has been evidence showing that such preference for positive adjectives over neutral or negative adjectives results in higher source memory accuracy for the former (Durbin et al., 2017). However, it is not clear whether the same advantage is prominent for recollection measured via the Remember/Know procedure rather than source information and when levels of closeness and familiarity are kept under experimental control.

## 3.2 Methods

### 3.2.1 Participants

Twenty-seven right-handed, native English speakers were recruited via opportunity sampling to participate in the experiment (mean age 19 years, range 18-21 years; 7 male). All participants had normal or corrected-to-normal vision and reported no history of neurological or psychological illness. Written consent forms were acquired before individuals participated in the experiment. They received 1 course credit per hour for their participation. The experimental procedures were approved by the University College London Research Ethics Committee.

The number of samples of each experiment was determined by previous studies addressing and demonstrating the SRE  (Gutchess, Kensinger, Yoon, et al., 2007; Leshikar et al., 2015) and ERP old/new effects in episodic memory (Galli et al., 2012; Otten et al., 2010; Otten et al., 2007).

### 3.2.2 Materials

A total of 264 English personality trait adjectives were selected from a database of written English words (Warriner, Kuperman, & Brysbaert, 2013). The trait adjectives were 4-9 letters in length and had 1-2 syllables. The word frequency of the adjectives was between 1 and 8005 per million. The valence and arousal of the selected adjectives were rated and reported in Warriner et al. (2013) using a nine-point scale (for valence, 1: unhappy, 9: happy, mean 4.98, range 2.04-8.47; for arousal, 1: calm, 9: excited, mean 4.25, range 1.67-6.95). Other linguistic properties were referenced to another database, the British Lexicon Project (Keuleers, Lacey, Rastle, & Brysbaert, 2012). In total, four sets of 66 adjectives were randomly selected from the material pool with the word frequencies, word lengths, syllable numbers, mean valence and mean arousal controlled across the four sets (all Fs < 1.4). Each set has equal numbers of Negative, Neutral and Positive adjectives (22 each valence), which were determined by the valence ratings from Warriner et al. (2013). The mean valences across sets for Negative, Neutral and Positive adjectives were 3.15, 4.78 and 6.90. The sets of adjectives were rotated across every four participants to create different study and test lists. For each participant, three of the four sets were used during the study phase as encoding items, one set each for the Self, Close Other and Distant Other conditions. The list of items during the test phase was constructed from the three old lists above, together with the fourth list as new items. In this manner, every adjective was rotated between all the conditions: Self, Close Other, Distant Other and New. In this case, the emotional valences were distributed equally to each encoding condition. The words were presented in written form in black, with a 50% grey background (visual angle was about 2.5 degrees horizontally and 1 degree vertically). An additional 12 adjectives were used for practice lists.

### 3.2.3 Design

The experiment used a three-by-three within-participant design. The independent variables were Reference Person (Self, Close Other and Distant Other) and Valence (Negative, Neutral and Positive). The dependent variable was the recognition memory performance measured by Remember/Know procedure.

### 3.2.4 Procedure

The experiment consisted of an incidental study phase, followed by a recognition memory test. During the study phase, three colours (red, blue and green) were randomly assigned to the three encoding conditions (Self, Close Other and Distant Other). The colours were used for the study cues prior to the presentation of each adjective (a coloured box). The use of colour cues, instead of text cues, eliminates perceptual differences between encoding conditions that may affect EEG responses in subsequent experiments. Before starting the experiment, a colour-blindness test (Ishihara, 1968) was given to participants to confirm the ability to discriminate between colours. Their familiarity of colour-condition mapping was verified with practice and confirmed by researchers before the experiment. The participants were then instructed to judge how consistent a trait adjective was with themselves, a close other or a distant other, depending on the colour of the cues.

The close other was determined via a bespoke and self-reported form for each participant. Participants were instructed to give the names of six people that they felt close to, name their relationship to each person and rate each person on the following four questions using a 10-point scale. The questions were: 1) ‘how well do you know the person?’, 2) ‘how well do you think the person knows you?’, 3) ‘how close do you feel you are to the person?’, and 4) ‘how close does the person feel to you?’ (1: not well at all, almost like a stranger; 10: very well, almost like myself). The participants were instructed to answer the ‘closeness’ of the questions 3 and 4 as the degrees of emotional attachment to each person (see Appendix B). Among these four questions, questions 1) and 3) are related to the subjective closeness and familiarity to each person, while questions 2) and 4) are related to the perception of the closeness and familiarity of each person to themselves. The name with the highest total score of questions of subjective closeness to each person (1 and 3) was assigned as the close other for a participant. To control for the variability of close others, questions of the perception of the closeness of each person to themselves (2 and 4) were designed to capture the situation that the closest person to the participant was not perceived as a mutually close person. None of the participants in this thesis reported this issue. In all cases of the thesis, the close other chosen for the participant also has the highest score of subjective closeness (question 3).

The distant other, a fictional character, was randomly chosen from a list of four: James Bond, Harry Potter, Sherlock Holmes and Homer Simpson. These are fictional characters that in the UK most undergraduate students are familiar with. Each participant was asked to rate how familiar they were with the chosen character using a 10-point scale with 1 meaning that they know nothing about the character, just like a stranger, and 10 meaning that they almost know everything about the character, just like themselves. If the rating given by the participant was lower than 7, another character from the list was assigned until it was rated equal or higher than 7. The familiarity matching procedure for a distant other was an attempt to contrast the subjective familiarity question (question 1) on the questionnaire for a close other. The second familiarity question (question 2) on the questionnaire was not able to be contrasted in the context of a fictional character, due to there was no way for a participant to evaluate how well a fictional character knows him or her selves. The purpose of assigning the fictional character to the participants from a list, instead of letting them choose their own character for the experiment, was to avoid a possible situation that participants might choose their favourite yet close character as the distant other for the experiment.

The encoding cue was presented for 1400 ms, prior to a personality trait adjective, to indicate the encoding condition of the trial. After a short blank period of 100 ms, an adjective was shown on screen for 500 ms. A fixation cross was presented for a random period between 3000 and 4500 ms until the next cue was presented. The judgments were given by pressing one of four response buttons with the right index, middle, ring or little finger to indicate whether the adjective was absolutely consistent, moderately consistent, moderately inconsistent or absolutely inconsistent to the person assigned by the cue. The order of the buttons was counterbalanced across participants. Both accuracy and response speed were instructed as equally important to the participants.

The test phase was performed 10 minutes after the end of the study phase. This delay period was filled with a tea break and the instructions of the test phase. During the test phase, all the studied adjectives were presented again, together with 66 new adjectives, which were not shown during the study phase. The task for the participants was a recognition memory test involving Remember/Know judgments (Tulving, 1985; Yonelinas, 2002). At the beginning of each trial, an exclamation mark ('!') was shown on the screen for 400 ms to alert the participants that they were about to see an adjective. After a blank period of 100 ms, an adjective was shown on screen for 1000 ms and the participants were instructed to give their response by pressing one of three buttons with their right index, middle or ring finger. A New judgement was to be made if they thought the adjective was not presented in the study phase; a Remember response if they could recollect contextual details about the previous occurrence of the adjective; and a Know response if they felt the adjective is familiar to them but failed to retrieve any specific details about the prior occurrence. The order of the fingers was counterbalanced across participants. After the presentation of an adjective, a fixation cross was presented on the screen as an inter-trial screen for a random period between 2500 ms and 4000 ms.

The study phase was separated into two blocks with a 1-minute break inserted in the middle; the test phase was divided into three blocks with two breaks. All conditions were intermixed randomly in both phases.

### 3.2.5 Analysis approach

Recognition memory in the current experiment was assessed by Pr, which considers the ability to discriminate between old and new items (Snodgrass & Corwin, 1988). The Pr values for each participant and condition were calculated using the formula 'Pr = hit - false alarm', to obtain a single number representing memory accuracy. With single numbers representing memory accuracy in each condition, the statistical comparisons on behavioural performance can be simple yet accurate. In order to differentiate the individual contributions of sub-components of episodic memory, the contributions of recollection and familiarity were further estimated using a similar manner. The contribution of recollection was estimated by subtracting the proportion of Remember responses given to new items from the proportion of Remember responses given to old items. The contribution of familiarity was estimated by applying a formula, 'Familiarity = Know/(1-Remember)' to correct for the fact that any old item that could not be recollected must be given a Know judgment (Yonelinas, 2002; Yonelinas & Jacoby, 1995). After the correction, the differences between familiarity to old items and new items were then calculated to represent the accuracy of familiarity. The formulae mentioned above are based on the assumption that recollection and familiarity are exclusive to each other. Because participants are allowed to make only one judgment when they recognise an item as being old, items that give rise to both recollection and familiarity receive Remember responses exclusively, instead of both Remember and Know responses. Know responses therefore underestimate the contribution of familiarity due to parts of the contribution going to Remember responses. This underestimation is corrected using the formulae above. It has been suggested that this calculation provides a better estimate of the contribution of recollection and familiarity for memory decisions (Yonelinas, 2002; Yonelinas & Jacoby, 1995). With the correction, the contribution of recollection and familiarity to the SRE can be compared.

To understand how self-referencing interacts with recollection/familiarity and emotion, the Pr values of recollection and familiarity were submitted to a repeated-measures ANOVA consisting of factors of emotional valence (negative, positive, neutral), reference person (self, close other, distant other), and memory type (recollection, familiarity). Reaction times during both study and test were analysed in order to monitor whether differences during the study phase might be able to account for differences observed during the test. It is worth mentioning that there is no accuracy data for the study task, due to the responses from participants being subjective. The purpose of the study task was to keep participants engaged during incidental encoding. Greenhouse-Geisser corrections were applied if the assumption of sphericity was violated (Picton et al., 2000).

## 3.3 Results

Trials with reaction times that were more or less than two standard deviations from the mean were identified in each participant as outliers and excluded from the subsequent analyses. The mean exclusion rates were .04 during the study phase (range .02-.09; mean for the Self, Close Other and Distant Other conditions were .04, .04 and .05 respectively) and .05 during the test phase (range .03-.08; mean for the Self, Close Other, Distant Other and New conditions were 0.04, 0.05, 0.06, and 0.04 respectively).

The subjective ratings of the closeness and familiarity questionnaire are presented in Table 3.1 (1: not well at all, almost like a stranger; 10: very well, almost like myself). The ratings reported are the numbers from the eventually chosen person out of the six people listed by the participant. The ratings fit the design of the experiment that both familiarity and closeness of the person chosen are at the ceiling of the scale.

*Table 3.1. Mean ratings (range 1 to 10) for a close other in the closeness and familiarity questionnaire.*

| Question | Rating (SD) |
|---|---|
| How well do you know the person? | 9.48 (.64) |
| How well do you think the person knows you? | 9.44 (1.01) |
| How close do you feel you are to the person? | 9.52 (.70) |
| How close do you think does the person feel to you? | 9.52 (.75) |

### 3.3.1 Recognition memory

Recognition memory performance was transformed to Pr values for each experimental condition (Table 3.2). A repeated-measure ANOVA with factors of Valence (Negative vs. Neutral vs. Positive), Reference Person (Self vs. Close Other vs. Distant Other), and Memory Type (Recollection vs. Familiarity) was employed for the analysis. The results indicated significant main effects of Valence (F(1.965, 51.081) = 3.573, $\eta_p^2$ = .121, p = .036; Table 3.2), Memory Type (F(1, 26) = 5.729, $\eta_p^2$ = .181, p = .024), and Reference Person (F(1.756, 45.654) = 7.719, $\eta_p^2$ = .229, p = .002). Participants showed better memory to Neutral adjectives than to Negative adjectives (.36 vs. .30; t(26) = 2.512, p = .019), to recollection than to familiarity, and importantly, to adjectives correlated with Self compared to both a Close Other (.37 vs. .32; t(26) = 2.913, p = .007) and a Distant Other (.37 vs. .32; t(26) = 3.250, p = .003; Figure 3.2). The differences between the Close Other and Distant Other (t(26) = .363, p = .720), Neutral and Positive (t(26) = .962, p = .345), and Negative and Positive (t(26) = 1.806, p = .083) conditions were not significant. The interactions between Valence and Memory Type (F(1.845, 47.962) = 1.205, $\eta_p^2$ = .044, p = .308), Valence and Reference Person (F(3.119, 81.085) = .815, $\eta_p^2$ = .030, p = .493), Memory Type and Reference Person (F(1.997, 51.933) = 1.648, $\eta_p^2$ = .060, p = .202) and Valence, Memory Type and Reference Person (F(3.696, 96.089) = .885, $\eta_p^2$ = .033, p = .469) were not significant.

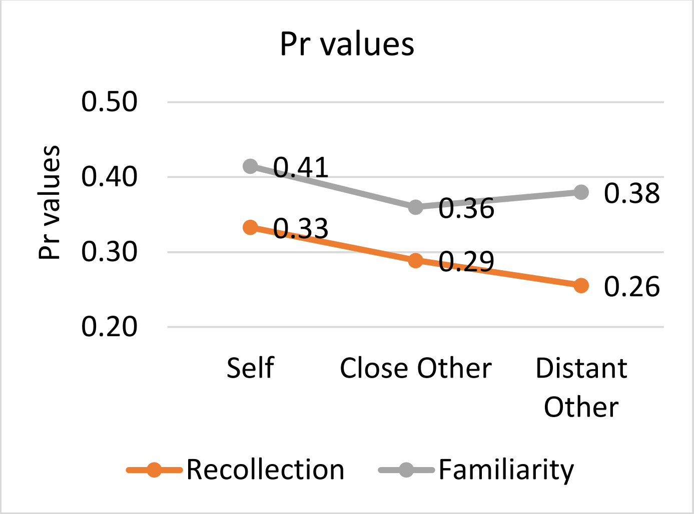

*Figure 3.2. Line graph for Pr values for the Self, Close Other and Distant Other conditions, separately for recollection and familiarity. Valences are collapsed.*

*Table 3.2. Pr values of recollection and familiarity for the Self and Other conditions, separated by emotional valence of the adjectives.*

| | | Recollection | | | | Familiarity | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Negative | Neutral | Positive | Mean | Negative | Neutral | Positive | Mean |
| Self | Mean | .29 | .33 | .38 | .33 | .40 | .44 | .40 | .41 |
| | SD | .17 | .20 | .22 | .20 | .25 | .22 | .25 | .24 |
| Close Other | Mean | .27 | .32 | .28 | .29 | .31 | .40 | .35 | .36 |
| | SD | .14 | .18 | .19 | .17 | .20 | .24 | .20 | .21 |
| Distant Other | Mean | .20 | .28 | .28 | .29 | .34 | .43 | .37 | .38 |
| | SD | .15 | .22 | .19 | .19 | .21 | .18 | .20 | .20 |

## 3.3.2 Reaction times

### 3.3.2.1 Study phase

The reaction times (shown in Table 3.3) were analysed using a repeated-measure ANOVA with factors of Reference Person (Self vs. Close Other vs. Distant Other) and Valence (Negative vs. Neutral vs. Positive). The results suggested significant main effects of Reference Person ($F(1.676, 43.582) = 7.159$, $\eta_p^2 = .216$, $p = .003$) and Valence ($F(1.870, 48.626) = 3.525$, $\eta_p^2 = .119$, $p = .040$), while the interaction was not significant ($F < 1.1$). Follow-up analyses revealed that participants took longer time to make a judgment about an adjective when it referred to Distant Other than Close Other (1492 ms vs. 1424 ms; $t(26) = 5.039$, $p < .001$), to Neutral than Negative items (1483 ms vs. 1443 ms; $t(26) = 2.237$, $p = .034$) and to Neutral than Positive items (1483 ms vs. 1447 ms; $t(26) = 2.565$, $p = .016$). The differences between the Self and Close Other ($t(26) = 1.660$, $p = .109$), Self and Distant Other ($t(26) = 1.775$, $p = .088$), and Negative and Positive ($t(26) = .177$, $p = .860$) conditions were not significant.

*Table 3.3. Reaction times for the Self, Close Other and Distant Other conditions during the study phase for negative, neutral and positive trait adjectives (in ms).*

| | | Emotion | | |
|---|---|---|---|---|
| | | Negative | Neutral | Positive |
| Self | Mean | 1456 | 1473 | 1439 |
| | SD | 264 | 241 | 222 |
| Close Other | Mean | 1413 | 1456 | 1404 |
| | SD | 262 | 248 | 228 |
| Distant Other | Mean | 1461 | 1519 | 1497 |
| | SD | 264 | 300 | 259 |

#### 3.3.2.2 Test phase

A repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other vs. Distant Other) and Memory Type (Remember vs. Know) was used to analyse the reaction times during the test phase. Levels of Valence were combined to avoid less insufficient (than 5) trials for each condition. The reaction times of Know responses were not possible to be transformed into Familiarity, hence the comparisons are based on Remember and Know responses, not Recollection and Familiarity as memory proportions. The results indicated that participants took longer to make a Know judgment than a Remember judgment (1288 ms vs. 1221 ms; $F(1.687, 43.874) = 3.831$, $\eta_p^2 = .128$, $p = .036$). The main effect of Reference Person was significant as well ($F(1, 26) = 4.631$, $\eta_p^2 = .151$, $p = .041$). The interaction between Reference Person and Memory Type was not significant ($F = .427$). Post-hoc t-tests suggested that participants took longer to make a judgment about an item when it had to be related to Distant Other than to Self (1271 ms vs. 1236 ms; $t(26) = 3.200$, $p = .004$). The difference between the Close Other and Distant Other (1256 ms vs. 1271 ms; $t(26) = -1.007$, $p = .323$), and Self and Close Other (1236 ms vs. 1256 ms; $t(26) = -1.705$, $p = .100$), conditions was not significant.

### 3.3.3 Summary

Similar to the findings in the literature, memory differed depending on which person a trait adjective had to be related to: items processed in relation to the self were remembered better than items processed in relation to a close other and distant other. This was true for both recollection and familiarity-based responses. No memory differences between a close other and distant other were found. Better memory for neutral items than negative items was also observed in this experiment. During encoding, participants took longer to respond to items related to a distant other than a close other.

When making memory decisions, participants took longer to make judgments about items processed in relation to a distant other than to the self.

## 3.4 Discussion

Experiment 1 was designed to address the first research question of the thesis: what is the effect of closeness to others on the SRE? This question was addressed with a design in which encoding conditions were equated for familiarity with another person but ranged in level of closeness. The close other condition was designed to be a person that was as close and familiar as possible to each participant. This design provided a basis to investigate whether closeness to others is a key factor in the SRE. Given that closeness and familiarity were equivalent between the self and the close other, any difference between the two must be due to factors other than closeness, for example, sense of the self or sense of agency (Decety & Sommerville, 2003; Klein, 2012). The distant other was designed to have a lower level of closeness than both the self and a close other, though this was not measured directly. It was predicted that memory accuracy for a distant other would be lower than the other two conditions, due to reduced levels of closeness being related to lower levels of memory accuracy in previous work (Czienskowski & Giljohann, 2002; Klein, 2012; Maki & McCaul, 1985; Symons & Johnson, 1997). Partially as predicted, a significant SRE was observed in the current experiment when the self was compared with both a close and distant other. This is in line with previous studies investigating the SRE (e.g., Gutchess et al., 2015; Leblond et al., 2016; Leshikar et al., 2015; Symons & Johnson, 1997) indicating that the self is not the same as a highly close other (Decety & Sommerville, 2003). The pattern of data also suggests that, at least when comparing the self with close others, the degree to which intimacy is felt to someone else cannot easily explain the presence of the SRE.

Interestingly, memory decisions about a distant other had longer reaction times than decisions about the self. It is not clear whether this pattern is consistent with previous findings in the literature because reaction times are rarely reported. Nevertheless, this pattern is consistent with the concept that the self is a dominant body that can be easily utilised to bind information with it and facilitate faster processing compared to familiar or unfamiliar others (Sui & Humphreys, 2015; H. X. Wang, Humphreys, & Sui, 2016). One might argue that the superior memory for the self is the result of self-referential processing at study being deeper (i.e., LOP, Craik & Lockhart, 1972). However, this is unlikely the case, given that there was no evidence that participants took longer to process items in relation to the self during encoding. If anything, the evidence suggests otherwise: participants took longer to process items in relation to a distant other than a close other, without resulting memory difference between the two conditions. Processing times thus increased the further away a person was from the self. Across the study and test phases, the distant other was the condition that participants took the longest time to respond to. This pattern might be because the subjective familiarity to a distant is still lower than both the self and a close other, even though the intention of the design is to keep the levels constant between conditions. It is also more likely that the longer reaction time to a distant other reflects combined effects of lower familiarity and closeness compared to the self and a distant other. Another possibility is that both the self and close others feel closer and more accessible due to them being part of daily life. They accordingly need less time to access when making decisions about trait adjectives. For a distant other, even though knowledge about the person is available, it is not accessed as frequently as knowledge of the self or a close other and therefore attract longer response times. Nevertheless, the subjective closeness and familiarity to the distant other for each participant were controlled but not explicitly measured, hence limited the interpretation of the results in the sense that individual variation was not considered in this case.

It was predicted that self-referenced encoding will encode more contextual details, hence boosting recollection in memory tests (Leshikar et al., 2015). However, the finding in this experiment was that items encoded in relation to the self showed enhanced recollection and familiarity than items processed in relation to a close other or a distant other. This pattern is not compatible with the idea of a selective effect on recollection. Such contradictory result might be due to the different control tasks used. Leshikar et al. (2015) used semantic encoding as their control condition for SR encoding, while the current experiment used other-referencing. The two encoding tasks may have differed in many ways. For example, the current encoding task is likely to involve demanding participants to recall vivid episodes of a fictional character, in order to judge whether the character fits the description of the trait adjectives. Through this process, which is absent in semantic encoding, more associations may have been linked to the adjectives and facilitate different proportions of recollection and familiarity in a later memory test. The process required by the current encoding task may have changed the relative contributions of recollection and familiarity and produced different results than Leshikar et al. (2015).

It was also predicted that memory accuracy for a distant other should be lower than memory accuracy for a close other given that this pattern has been demonstrated in some previous studies (Czienskowski & Giljohann, 2002; Klein, 2012; Maki & McCaul, 1985; Symons & Johnson, 1997). However, what was found in the current experiment was that memory accuracy for a close other and that for a distant other did not differ, even though recollection showed a non-significant trend of reduced memory for a distant other. In the literature, the SRE is usually larger when the self is compared with a distant other rather than close other (Czienskowski & Giljohann, 2002; Klein, 2012; Maki & McCaul, 1985; Symons & Johnson, 1997). This was thought to be driven by enhanced elaboration processes during the encoding of information related to more distant others (Symons & Johnson, 1997). There was no evidence in the current case that memory accuracy for a close other was higher than that for a distant other. Following the rationale that elaboration processes may be responsible for the different levels of memory accuracy of close and distant others, the equivalent memory accuracy in the two conditions in this experiment may imply that they were processed with similar levels of elaboration. Even though this is a difficult issue to be addressed, the reaction times during encoding may reveal whether these two conditions were processed differently. The data suggest that participants took longer to process items in relation to a distant other than to a close other, instead of showing equivalent reaction times in the two conditions. The different reaction times do not suggest that the two conditions were processed uniformly. One of the other reasons might be because different types of memory tests were used in the current experiment and in the literature. It is worth noting that early studies of SRE were largely based on recall tasks to estimate memory (e.g., Keenan & Baillet, 1980; Maki & McCaul, 1985). It is not clear whether a Remember/Know procedure will result in the same estimations. One of the possibilities is that memory for a distant other is larger with the Remember/Know procedure than with recall. The former counts the retrieval of any contextual details as recollection, whereas the latter limits recollection to the link between the person and the trait adjectives established during encoding (i.e. source information). This speculation can be tested using a source memory paradigm, instead of the Remember/Know procedure, to estimate memory decisions that are supported by only links between the person and trait adjectives. Nevertheless, when considering both recollection and familiarity at the same time, there was a trend of reflecting a difference between the overall recognition accuracy of a close other and a distant other. However, this trend was not supported by the statistical analysis possibly due to the small sample size and lack of sufficient power of this experiment.

It was also predicted that positive items should elicit higher memory accuracy than neutral and negative items due to the tendency to keep a positive self-image (Zhang et al., 2013). A previous study indeed suggested that positive items have higher source memory accuracy relative to other emotions (Durbin et al., 2017). However, what was found in the current experiment was no interaction between the self and emotion. This does not support the perspective that keeping a positive self-image benefits source memory accuracy. However, the response proportions during study suggest that participants made more consistent than inconsistent judgments to positive items (respectively .66 vs .33; the proportions were not presented in detail for simplicity), which supports the notion of keeping a positive self-image. These data also suggest that, even though participants may be trying to keep a positive self-image, memory does not always benefit from this attempt. In this experiment, neutral items were remembered better than both emotional (i.e. negative and positive) items. This finding adds one more observation to the debate in the literature whether emotional stimuli always boost memory traces (Bisby & Burgess, 2014; Cook et al., 2007; Yick et al., 2015). Interestingly, the reaction times during study suggest that participants took longer to make decisions about neutral than negative and positive items. This may reflect that the better memory for neutral items is due to longer processing times, and perhaps enhanced elaboration, during study. For neutral items, the participants may have evaluated more episodes before they made judgements and hence produced more associations between the items and a person (i.e. a deeper encoding).

To conclude, Experiment 1 addressed the question of whether closeness to others is a key factor in the SRE. The results suggest that closeness to others cannot exclusively explain the presence of the SRE, because it was found that the self still elicited higher memory accuracy compared to a close other with comparable levels of closeness. In addition, memory accuracy of a distant other was not different from that of a close other, leaving no evidence that closeness affects the SRE. However, it is not clear to what extent the current memory test was able to properly detect the associations established during encoding. This issue can be addressed using an objective source memory test, instead of a subjective measure. Experiment 2 adopted this approach.

# Chapter 4. Experiment 2: behavioural self-reference effect with the self, close other and distant other with source memory

## 4.1 Introduction

In Experiment 1, a significant SRE was found for the self compared to both a close and distant other. The significant difference between the self and a close other, with equivalent levels of closeness, implies that closeness to others cannot exclusively explain the presence of the SRE. However, the results did not reveal higher memory accuracy for the close other relative to a distant other, as has been found in the literature. It is not clear whether the equivalent memory accuracy between the close and distant other is due to the subjective Remember/Know memory procedure used in Experiment 1. Additional evidence via an objective source memory task will substantiate the pattern of results found in Experiment 1. In Experiment 2, memory was tested with an objective memory test, the source memory paradigm (Vallesi & Shallice, 2006; Wilding & Rugg, 1996), in which the participants were instructed to identify the person processed with the item during encoding. This paradigm allows the experiment to address whether the patterns found in Experiment 1 still exist when source information established during encoding has to be reported during the memory test.

To date, there are only a few SRE studies that have used a source memory task (e.g., Dulas et al., 2011; Durbin et al., 2017), and, to my knowledge, no studies have compared the SRE with Remember/Know and source memory procedures. Dulas et al. (2011) instructed participants to incidentally encode object photos, after which memory was tested using a source memory paradigm. Their results suggested no difference on item memory between the self-reference and control conditions, while a significant difference was found for source memory accuracy. However, there is a chance that the equivalent item memory accuracy in their study is a result of a ceiling effect (~90% overall accuracy), instead of actually reflecting no difference between the two conditions. Durbin et al. (2017) addressed the SRE on item and source memory and found an SRE on item memory regardless of emotional valence of an item. An SRE on source memory, in contrast, was only found for positive items. The authors argued that different mechanisms are involved in item and source SREs, where item SREs depend on the overall likelihood of non-self-associations created by the item, whereas source SREs depend on the likelihood of the stimuli triggering an association to one's self-schema. The findings from these previous studies may suggest that the presence of the SRE depends on how memory is tested.

In Experiment 2, a source memory paradigm was used to analyse SREs in both item memory and source memory (Wilding & Rugg, 1996). Item memory refers to overall memory accuracy, regardless of whether or not contextual information associated with an item can be recollected. On the other hand, source memory refers to memory decisions supported by correct source information. The source memory paradigm allows the experimenter to investigate whether memory decisions are supported by knowledge about the specific person that information was encoded in relation to, instead of any contextual details associated with the items. The latter is captured by the Remember/Know paradigm. There have been studies suggesting that in most cases, old/new recognition measured by Remember/Know and source memory paradigms are comparable (Hicks & Marsh, 1999; Khoe, Kroll, Yonelinas, Dobbins, & Knight, 2000). However, there have also been studies suggesting that if the instructions ask participants to focus on perceptual details, recognition accuracy may be changed qualitatively and produce different results across Remember/Know and source memory paradigms (Mulligan, Besken, & Peterson, 2010; Mulligan & Osborn, 2009). Although the information used during a self-reference encoding task might be mostly conceptual in nature given that it involves judgments about personality traits, perceptual information retrieved in the process may affect later memory judgments.

In Experiment 2, a source memory paradigm is used, and it is predicted that item memory should yield a similar pattern as in Experiment 1. Item memory should be highest for items encoded in relation to the self rather than both a close and distant other. This is because Experiment 1 found this pattern regardless of recollection or familiarity. The pattern of source memory should reveal whether the finding in Experiment 1 that memory accuracy did not differ between a close and distant other can indeed be explained by the particular source information that is encoded. If the answer is yes, then a similar pattern is expected in the current experiment. If not, the source memory may be different for close and distant other.

It is also predicted that source memory accuracy will be higher for emotional than neutral items because studies have suggested that more source information is retrieved for such items (Doerksen & Shimamura, 2001; Yick et al., 2015). Specifically, it is predicted that source memory will be higher for positive items that are processed in relation to the self, due to the tendency to have a positive self-image (Durbin et al., 2017). An additional analysis on the item memory across Experiment 1 and 2 were carried out to address whether the difference between a close other and a distant other in Experiment 1 can be revealed if the power increases.

## 4.2 Methods

### 4.2.1 Participants

Thirty-two right-handed, native English speakers volunteered to participate in the experiment (mean age 20 years old, range 18-30 years old; 5 male). All participants had normal or corrected-to-normal vision and reported no history of neurological or psychological illness. Written consent forms were acquired before individuals participated in the experiment. They received one course credit per hour for their participation. The experimental procedures were approved by the University College London Research Ethics Committee.

### 4.2.2 Materials

The materials used in this experiment were identical to those in Experiment 1, consisting of four lists of 66 trait adjectives. Three of the lists were used during the study phase. The last list of materials was used as new items during the test phase. Each list contained equal numbers of negative, neutral and positive adjectives. The words were presented in written form in black, with a 50% grey background (visual angle was about 2.5 degree horizontally and 1 degree vertically). An additional 12 adjectives were used for the practices.

### 4.2.3 Procedure

The procedure of the study phase was identical to that of Experiment 1. Participants made consistency judgments about trait adjectives in relation to the Self, a Close Other or a Distant Other. After a 5-minute break, the test phase was introduced to the participants. The recognition memory test in this experiment differed from that in Experiment 1. In the current experiment, instead of a one-step Remember/Know procedure, a one-step source memory decision was employed to evaluate source memory accuracy. Participants were instructed to distinguish between new and old adjectives by indicating whether the item presented was new, old and processed in relation to the Self, old and processed in relation to a Close Other, old and processed in relation to a Distant Other, or old without knowing the associated person. The responses were given with the right thumb, index, middle, ring or little finger. The assignment of the response options to fingers was counterbalanced across participants.

As in Experiment 1, before the experiment started, the Close Other and Distant Other were assigned separately for each participant with the same procedures.

### 4.2.4 Analysis approach

Memory performance was analysed in terms of item memory accuracy and source memory accuracy. This allows the results to reveal differences between overall recognition and decisions supported by source information. Similar to the approach used in Experiment 1, item memory was assessed by subtracting false alarm rates from hit rates, thus calculating Pr (Snodgrass & Corwin, 1988). Source memory accuracy was calculated from the proportion of old items for which the associated person could be correctly retrieved minus the proportion of new items mistakenly given a source judgment. This approach is similar to what has been used in the literature to address item and source memory (Wilding & Rugg, 1996). The reaction times to old items during the test phase were analysed with a factor of source memory accuracy (source correct vs. source incorrect). The factor of emotion was collapsed to avoid insufficient trial numbers (less than 5) for each condition. The reaction times during the study phase were analysed with the same approach as in Experiment 1.

## 4.3 Results

Trials with reaction times more or less than two standard deviations from the mean were identified as outliers and excluded from the subsequent analysis. The mean exclusion rates were .04 for the study data (max .06; min .01; mean for the Self, Close Other and Distant Other conditions were .04, .05 and .06), and .05 for the test data (max .08; min .03; mean for the Self, Close Other, Distant Other and New conditions were 0.03, 0.06, 0.05 and 0.04). The subjective ratings of the closeness and familiarity questionnaire are presented in Table 4.1 (1: not well at all, almost like a stranger; 10: very well, almost like myself). The ratings reported are the numbers from the eventually chosen person out of the six people listed by the participant. The ratings fit the design of the experiment that both familiarity and closeness of the person chosen are at the ceiling of the scale.

*Table 4.1. Mean ratings (range 1 to 10) for a close other in the closeness and familiarity questionnaire.*

| Question | Rating (SD) |
|---|---|
| How well do you know the person? | 9.28 (.81) |
| How well do you think the person knows you? | 9.50 (.62) |
| How close do you feel you are to the person? | 9.56 (.62) |
| How close do you think does the person feel to you? | 9.31 (.93) |

## 4.3.1 Recognition memory

### 4.3.1.1 Item memory

The Pr values for item and source memory for the Self, a Close Other and a Distant Other are listed by emotional valence in Table 4.2. The Pr values for item memory were analysed with a repeated-measure ANOVA with factors of Valence (Negative vs. Neutral vs. Positive) and Reference Person (Self vs. Close Other vs. Distant Other). This analysis showed significant main effects of Valence (F(1.859, 57.622) = 73.188, $\eta_p^2$ = .702, p < .001) and Reference Person (F(1.656, 51.321) = 31.095, $\eta_p^2$ = .501, p < .001). Subsequent subsidiary analyses indicated that item memory for Positive items was higher than that for Neutral (.39 vs. .21; t(31) = 9.511, p < .001) and Negative (.39 vs. .22; t(31) = 10.500, p < .001) items. Item memory for the Self was higher than that for the Close Other (.33 vs. .28; t(31) = 4.724, p < .001) and Distant Other (.33 vs. .21; t(31) = 6.797, p < .001; Figure 4.1) conditions, and item memory for the Close Other was higher than that for the Distant Other (.28 vs. .21; t(31) = 4.062, p < .001; Figure 4.1). The interaction between Valence and Reference Person was not significant (F(3.577, 110.895) = .003, $\eta_p^2$ = .009, p = .276).

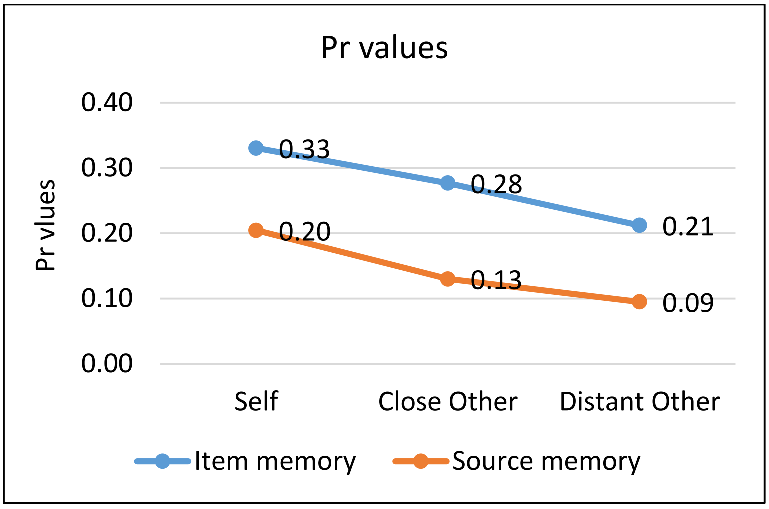

*Figure 4.1. Line graph of Pr values for the Self, Close Other and Distant Other conditions, separately for item and source memory. Valences are collapsed.*

*Table 4.2. Pr values for item and source memory for the Self, Close Other and Distant Other conditions, separately for each emotional valence, Experiment 2.*

| | | Negative | | | Neutral | | | Positive | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Self | Close Other | Distant Other | Self | Close Other | Distant Other | Self | Close Other | Distant Other |
| Item memory | Mean | 0.28 | 0.22 | 0.15 | 0.26 | 0.21 | 0.14 | 0.45 | 0.39 | 0.34 |
| | SD | 0.14 | 0.15 | 0.15 | 0.14 | 0.16 | 0.14 | 0.17 | 0.17 | 0.16 |
| Source memory | Mean | 0.21 | 0.11 | 0.10 | 0.20 | 0.13 | 0.09 | 0.21 | 0.15 | 0.10 |
| | SD | 0.22 | 0.11 | 0.11 | 0.21 | 0.14 | 0.15 | 0.23 | 0.18 | 0.12 |

#### 4.3.1.2 Source memory

The Pr values for source memory were analysed with a repeated-measures ANOVA with factors of Valence (Negative vs. Neutral vs. Positive) and Reference Person (Self vs. Close Other vs. Distant Other). The analysis showed a significant main effect of Reference Person (F(1.627, 50.438) = 6.311, $\eta_p^2$ = .169, p = .006). The main effect of Valence (F(1.773, 54.978) = .353, $\eta_p^2$ = .011, p = .678) and the interaction between Reference Person and Valence (F(3.197, 99.117) = .472, $\eta_p^2$ = .015, p = .714) were not significant. Subsequent analyses indicated that source memory was higher for the Self than a Close Other (.20 vs. .13; t(31) = 2.474, p = .019) and Distant Other (.20 vs. .09; t(31) = 2.899, p = .007). The difference between a Close Other and Distant Other was not significant (.13 vs. .09; t(31) = 1.425, p = .164; Figure 4.1).

#### 4.3.1.3 Pooled item memory of Experiment 1 and 2

To contrast with the item memory in Experiment 2, the item memory in Experiment 1 was calculated with the same way: using Pr values of raw hit rates and false alarm rates for each Reference Person and Valence to represent the item memory accuracy, regardless types of memory (recollection/familiarity), as shown in Table 3.1 (item memory accuracy of Experiment 2 is shown in Table 4.2 above).

The Pr values of Experiment 1 and Experiment 2 were submitted to a repeated-measure ANOVA with factors or Experiment (Experiment 1 vs Experiment 2), Valence (Negative vs. Neutral vs. Positive) and Reference Person (Self vs. Close Other vs. Distant Other). The results suggested significant main effects of Experiment (F(1, 57) = 41.208, $\eta_p^2$ = .420, p < .001), Valence (F(1.924, 109.665) = 17.241, $\eta_p^2$ = .232, p < .001) and Reference Person (F(1.953, 111.326 = 32.316, $\eta_p^2$ = .326, p < .001). Subsequent analysis indicated that the item memory accuracy was higher for Experiment 1 than Experiment 2 (.50 vs. .27, t(57) = 6.419, p < .001) and higher for Positive than both Neutral (.44 vs. .36, t(58) = 3.170, p = .002) and Negative (.44 vs. .33, t(58) = 5.495, p < .001) items, while the difference between Neutral and Negative items was not significant (.36 vs. .33, t(58) = 1.552, p = .126). Importantly, the item memory accuracy for Self is higher than both Close Other (.43 vs. .37, t(58) = 5.171, p < .001) and Distant

Other (.43 vs. .33, t(58) = 3.125, p < .001), and the accuracy for Close Other is higher than Distant Other (.37 vs. .33, t(58) = 7.391, p < .001).

The interaction between Experiment and Valence was significant (F(1.924, 109.665) = 26.991, $\eta_p^2$ = .321, p < .001). Supplementary analysis separated by Experiment suggested that for Experiment 1, the item memory accuracy was higher for Neutral items than Negative items (.54 vs. .47, t(26) = 2.381, p = .025). The differences between Neutral and Positive items (.54 vs. .49, t(26) = 1.703, p = .100) and between Negative and Positive items (.47 vs. .49, t(26) = .571, p = .573) were not significant. For Experiment 2, the item memory accuracy for Positive items was higher than both Neutral (.39 vs. .20, t(31) = 9.511, p < .001) and Negative (.39 vs. .22, t(31) = 10.500, p < .001) items. The difference between Neutral and Negative items was not significant (.21 vs. .22, t(31) = .755, p = .456).

The interaction between Experiment and Reference Person was also significant (F(1.953, 111.326) = 4.894, $\eta_p^2$ = .079, p < .001). Follow-up analysis separated by Reference Person suggested that for Experiment 1, the item memory accuracy for Self was higher for both Close Other (.54 vs. .48, t(26) = 2.998, p = .006) and Distant Other (.54 vs. .48, t(26) = 3.774, p = .001). The difference between Close Other and Distant Other was not significant (.48 vs. .48, t(26) = .132, p = .896). For Experiment 2, the item memory accuracy was higher for Self than both Close Other (.33 vs. .28, t(31) = 4.724, p < .001) and Distant Other (.33 vs. .21, t(31) = 6.797, p < .001), but also for Close Other than Distant Other (.28 vs. .21, t(31) = 4.062, p < .001).

The interactions between Experiment, Valence and Reference Person (F(3.709, 211.424) = .215, $\eta_p^2$ = .004, p = .919) and between Valence and Reference Person (F(3.709, 211.424) = .690, $\eta_p^2$ = .012, p = .589) were not significant.

*Table 4.3. Pr values for item memory for the Self, Close Other and Distant Other conditions, separately for each emotional valence, Experiment 1.*

| | | Negative | | | Neutral | | | Positive | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Self | Close Other | Distant Other | Self | Close Other | Distant Other | Self | Close Other | Distant Other |
| Item memory | Mean | .52 | .45 | .44 | .56 | .53 | .52 | .53 | .45 | .47 |
| | SD | .19 | .15 | .16 | .21 | .23 | .21 | .21 | .20 | .20 |

### 4.3.2 Reaction times

#### 4.3.2.1 Study phase

The reaction times (shown in Table 4.4) were analysed using a repeated-measures ANOVA with factors of Reference Person (Self vs. Close Other vs. Distant Other) and Valence (Negative vs. Neutral vs. Positive). The analysis showed a significant main effect of Reference Person (F(1.800, 55.808) = 16.817, $\eta_p^2$ = .352, p < .001). The main effect of Valence (F(1.749, 54.210) = 3.108, $\eta_p^2$ = .091, p = .059) and the interaction between Reference Person and Valence (F(3.190, 98.887) = 2.287, $\eta_p^2$ = .069, p = .080) were not significant. Follow-up analyses revealed that participants took longer to make a judgment about a Distant Other than Close Other (1394 ms vs. 1322 ms; t(31) = 4.489, p < .001) and the Self (1394 ms vs. 1316 ms; t(31) = 4.785, p < .001). The difference between the Self and a Close Other was not significant (t(31) = .442, p = .662).

*Table 4.4. Reaction times (in ms) for the Self, Close Other and Distant Other conditions during the study phase, separately for each emotional valence.*

| | | Emotion | | |
|---|---|---|---|---|
| | | Negative | Neutral | Positive |
| Self | Mean | 1347 | 1342 | 1296 |
| | SD | 319 | 322 | 296 |
| Close Other | Mean | 1314 | 1362 | 1300 |
| | SD | 328 | 338 | 325 |
| Distant Other | Mean | 1423 | 1383 | 1395 |
| | SD | 346 | 339 | 328 |

#### 4.3.2.2 Test phase

A repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other vs. Distant Other) and Source Memory (Source Correct vs. Source Incorrect) was used to analyse the reaction times during the test phase. The analysis showed a significant main effect of Reference Person (F(1.853, 57.431) = 3.603, $\eta_p^2$ = .104, p = .037). Follow-up analyses indicated that participants took longer to make judgments about Distant Others than the Self (1488 ms vs. 1413 ms; t(31) = 2.559, p = .016). The difference between the Self and a Close Other (1413 ms vs. 1461 ms; t(31) = 1.933, p = .062) and between Close Other and Distant Other (1461 ms vs. 1488 ms; t(31) = 1.014, p = .319) were not significant. The main effect of Source Memory (F(1, 31) = .328, $\eta_p^2$ = .010, p = .571) and the interaction between Reference Person and Source Memory (F(1.884, 58.419) = .777, $\eta_p^2$ = .024, p = .457).

### 4.3.3 Summary

Again, the self elicited the highest item memory and source memory compared to close and distant others. Interestingly, for item memory, the memory for the self was higher than that for the close other, and the memory for the close other was also higher than that for the distant other. This pattern is different from what was found in Experiment 1 and the prediction of this experiment. However, for source memory, accuracy was higher for the self than both a close other and distant other, with accuracy not differing between the latter two. Item memory was also better for positive items relative to negative and neutral items. There was no evidence for a significant interaction between the reference person and emotional valence for either item memory or source memory. Consistent with what was found in Experiment 1, reaction times during the study phase were longer for a distant other than both the self and a close other. The same pattern of longer reaction times for a distant other was also found during memory retrieval. Cross-experiment analysis on item memory accuracy suggested that when pooling samples from both experiments together, the item memory for the self was higher than that for the close other, and the item memory for the close other was also higher than that for the distant other.

## 4.4 Discussion

In Experiment 1, it was found that memory performance was better for the self than both the close other and the distant other. It was not clear whether this reflected better recollection of the particular person about which a judgment had to be made or some other contextual information. Experiment 2 was designed to address this issue with an objective source memory test. During the test, participants were instructed to indicate the person they had initially made a judgment about. With this assessment, the proportion of memory decisions exclusively supported by relevant source information can be estimated. It was predicted that item memory should replicate the patterns found in Experiment 1. On the other hand, source memory was predicted based on whether the memory decisions found in Experiment 1 were supported by source information. If yes, a similar pattern to Experiment 1 would be found.

Interestingly, item memory showed a different pattern from Experiment 1: memory accuracy for the self was higher than that for a close other and a distant other, while accuracy for a close other was also higher than that for a distant other. In addition, it was found that the pattern of source memory was not different from the memory accuracy found in Experiment 1: in this experiment, source memory was better for the self than both a close other and a distant other, with no significant difference between the two types of others. Interestingly, when pooling the sample from both experiments to increase the statistical power, significant gradual decrease of item memory across the item memory of the self, a close other and a distant other was found. This finding is partially in line with previous studies using a source memory paradigm to investigate the SRE (Dulas et al., 2011; Durbin et al., 2017). These studies found that SR either benefits item or source memory, but not both. What was found in the current experiment is that the self always produced better memory accuracy regardless of retrieving item or source information. Additionally, the gradual decrease of item memory across the self, close and distant other conditions suggest that closeness to others is able to explain other-referenced memory. The difference between the closeness of close and distant others may reflect the difference on item memory. However, in this experiment, a close other was designed to be the closest person to the self (the subjective closeness rating to a close other is 9.56 out of 10). If closeness underlies the SRE, there should not be a significant difference between the self and close other. The results suggested otherwise as a significant SRE was observed between the self and close other despite comparable levels of closeness. The sense of the self or agency may thus be a more important factor in producing the SRE than feeling close to others.

Interestingly, source memory showed a different pattern than item memory: source accuracy was not higher for a close other than a distant other, while on item memory, such the accuracy was higher for a close other than a distant other. The different SRE patterns between item and source memory might be due to several reasons. One speculation is that when memory decisions rely on source rather than item information, the accuracy decreases of the three conditions are not equivalent. This speculation is based on the observation that the difference between item and source memory of a close other (.15) is larger than both the self (.13) and a distant other (.12). Even though the differences were not statistically significant, it may suggest that a close other has the least source information available when making memory decisions. Interestingly, this speculation may be related to previous studies suggesting that during memory retrieval, participants tend to confuse the source between themselves and a close other, but not a distant other (the 'source confusion': Allan et al., 2017; Benoit et al., 2010; Bergström et al., 2015). The confusion may produce unequal decreases to the self and a close other and resulted in the pattern observed. However, this speculation was not supported by the number of source errors during memory retrieval. It was found that the numbers of items being mistakenly identified as a close other or the self are equivalent across the self and a close other conditions (mean number of error items 10 vs. 10). Nevertheless, there was a trend suggesting that the number of items confused between the self and a close other (mean number 20) is more than the number of items confused between the self and a distant other (mean number 13) and between a close other and a distant other (mean number 15), though this trend was not statistically significant (p = .087) hence no evidence suggesting the ‘source confusion’ in this experiment. One might also argue that the different patterns between item and source memory are due to different response criteria being set for the three encoding conditions. When comparing the item memory of the three conditions, the different response criteria yielded different patterns from their source accuracy. However, the Pr measure used to index memory accuracy in the current experiment takes response bias into consideration by subtracting false alarms from hits (Snodgrass & Corwin, 1988).

It is worth noting that the Pr values for source accuracy are relatively low in this experiment (.20, .13 and .09 for the self, a close other and a distant other). The non-significant difference between the close and distant other might be explained by a floor effect for the distant other. On the other hand, source memory accuracy showed a similar pattern to recollection in Experiment 1. These patterns confirm that the SRE observed in Experiment 1 is indeed supported by source information relating to the particular person that a decision was made about. However, it is not entirely clear why item memory in the current experiment was not compatible with overall memory accuracy in Experiment 1, given that both experiments used virtually identical procedures apart from the type of memory test. One possibility is that using a source memory rather than Remember/Know procedure changes the orientation of memory retrieval, thereby affecting item and source memory. It has been shown that old/new recognition can be based on more perceptually-driven information when the instructions shift from a Remember/Know procedure to a source-monitoring task (Mulligan et al., 2010). In the context of Experiments 1 and 2, it is possible that when participants were instructed to do a source memory task, they based their search on specific source information and may have failed to retrieve more general information about the episode hence resulted in lower accuracy. This change in orientation may result in decreased recognition accuracy for the distant other in Experiment 2.

Similar to Experiment 1, it was found that participants took longer to make a judgment about a distant other rather than the self or a close other. This was observed during both encoding and retrieval. This pattern might reflect that the information about the distant other is less accessible, as discussed previously in Experiment 1. Interestingly, positive items were in the current experiment remembered better than both negative and neutral items, regardless of the person correlated with the adjective. This finding is in line with studies showing that emotional items are remembered better due to more attentional resources being allocated to them during encoding (Doerksen & Shimamura, 2001; Yick et al., 2015). Nevertheless, this is different from what was found in Experiment 1, namely that neutral items elicited better memory than emotional items. It is not clear why this difference occurred.

The findings of Experiment 1 and Experiment 2 provided useful insights into the mechanisms of the SRE. Collectively, the data suggest that closeness to others cannot explain the SRE, an effect that is found using both subjective and objective memory tasks. Another approach to address the factor driving the SRE is from the perspective of individual differences. There have been studies suggesting that individual differences (e.g., self-esteem) can affect SREs across different emotional valences (Jones & Brunell, 2014; Zhang et al., 2013). However, the link between such individual differences and closeness has not yet been systematically investigated. This will be the focus of Experiment 3 in the next chapter.

# Chapter 5. Experiment 3: individual differences in the behavioural self-reference effect with the self and distant other

## 5.1 Introduction

Experiments 1 and 2 investigated whether closeness to others is a key factor to the SRE. There have been studies showing that individual differences can also affect the SRE (Jones & Brunell, 2014; Zhang et al., 2013). More specifically, Jones and Brunell (2014) found that self-esteem is related to valence effects in the SRE: self-esteem predicts higher recall rates for positive adjectives and lower recall rates for negative adjectives for self-referenced compared to other-referenced memory. This finding has been interpreted as an effect of integrating positive traits better with self-schema during encoding, resulting in a deeper encoding for positive than negative traits. This is due to mnemic neglect (Pinter et al., 2011) and shallower processing of the negative traits. In cases of mnemonic neglect, participants tend to selectively forget threatening information, such as negative traits. In addition, in previous findings of this thesis, it was found that participants made more consistent than inconsistent judgments to positive items related to themselves. However, this preference during encoding did not always benefit recognition memory performance. While this was found in Experiment 2, it did not occur in Experiment 1. This pattern is thus partially consistent with the influence of self-esteem mentioned above, which promotes more consistent judgments to positive items and extends the effect of preferring positive traits from memory encoding to retrieval (Jones & Brunell, 2014). Based on these observations, further investigation of the relationship between individual differences in self-esteem and the SRE seems warranted to provide more insights into the mechanisms underlying the SRE.

Self-esteem refers to the negative or positive evaluation of oneself (Coopersmith, 1967). It is relevant to how a person thinks about, or looks at, himself or herself. People with higher self-esteem are in general satisfied and attach a higher value to themselves, relative to people with lower self-esteem. Self-esteem is thought to be stable from childhood to adult (Trzesniewski, Donnellan, & Robins, 2003), but variable in response to the daily experience of the individual, for example, due to criticism received from others (Pyszczynski, Solomon, Greenberg, Arndt, & Schimel, 2004; Schimel et al., 2001).

In addition to self-esteem, this experiment is also interested in the effect of the Big-Five traits to extend and explore individual differences in the SRE, (John & Srivastava, 1999; Komarraju et al., 2011). The Big-Five traits represent a systematic view of the stable and long-term status of an individual, which is different from the mood and states that are variable across short periods of time. The Big-Five traits include five dimensions of personality: 1) conscientiousness (being disciplined, organised and goal-oriented), 2) neuroticism (being emotionally unstable, impulsive and anxious), 3) extraversion (being sociable, confident and talkative), 4) openness (being curious and open to new experience) and 5) agreeableness (being helpful, cooperative and sympathetic to others). The personality traits of any individual comprise independent combinations of the five dimensions.

To provide estimations of self-esteem and the Big-Five traits, two subjective questionnaires are used in the current experiment: the Rosenberg Self-Esteem Scale (Gray-Little, Williams, & Hancock, 1997) and The Big-Five Inventory (John & Srivastava, 1999). Both questionnaires are effective and efficient tools to estimate the relevant personality characteristics (Gray-Little et al., 1997; John & Srivastava, 1999). The Rosenberg Self-Esteem Scale is a 10-item subjective scale that measures the global self-worth of an individual. The questions consist of statements that describe positive and negative feelings about oneself (e.g., ‘On the whole, I am satisfied with myself.’ vs. ‘I feel I do not have much to be proud of.’). All questions are answered on a four-point Likert scale. The Big-Five Inventory is a 44-item subjective scale that measures the personality characteristics along the five dimensions of the Big-Five traits. The questions consist of descriptions of personality characteristics, e.g., ‘can be tense’; ‘is talkative’. Participants give responses with a 5-point Likert scale to indicate their subject ratings to the descriptions. With these two questionnaires, the self-esteem and the Big-Five traits of the participants can be measured and used to investigate their relationship with the SRE. The current experiment compared ratings about the self with those about a distant other. The condition of a close other was taken out of the design of the experiment. This was necessary to simplify the statistical comparisons.

It is unknown to what extent individual differences affect recollection, familiarity, or both (Jones & Brunell, 2014). Therefore, Experiment 3 used the Remember/Know procedure, similar to Experiment 1, to evaluate the effect of self-esteem and Big-Five characteristics on the SRE. It is predicted that low self-esteem is associated with a larger SRE, primarily for Remember responses (recollection) and positive items. This prediction is based on the previous finding that low self-esteem individuals promote memory for positive items by encoding them at a deeper level than negative items (Jones & Brunell, 2014; Zhang et al., 2013). For participants with high self-esteem, it is predicted that they have a typical SRE across the board, with memory boosted regardless of valence of an item. Studies have indicated that self-esteem is positively correlated with extraversion, agreeableness, openness and conscientiousness and negatively with neuroticism (Robins, Tracy, Trzesniewski, Potter, & Gosling, 2001). These findings suggest that the patterns of self-esteem and Big-Five traits will be correlated, at least to some extent.

## 5.2 Methods

### 5.2.1 Participants

Thirty-two right-handed, English native speakers (mean age 19 years, range 18-21 years old; 3 male) volunteered to participate in the experiment. All participants had normal or corrected-to-normal vision and reported no history of neurological or psychological illness. Written consent forms were acquired before individuals participated in the experiment. They received 1 course credit per hour for their participation. The experimental procedures were approved by the University College London Research Ethics Committee.

### 5.2.2 Materials

The materials used in this experiment were similar to those in Experiments 1 and 2, except that the 264 adjectives were randomly separated into three lists instead of four. This arrangement resulted in three lists of 88 items each. Two of the lists were assigned to the self and distant other conditions during encoding. The last list was used as new items during retrieval. The word frequencies, word lengths, syllable numbers, mean valence and mean arousal were controlled across lists as in previous experiments (see 3.2.2 Materials). The words were presented in written forms in black, against a 50% grey background (visual angle was about 2.5 degree horizontally and 1 degree vertically). Twelve additional adjectives were used in the practices.

### 5.2.3 Procedure

The procedure of the experiment was identical to that of Experiment 1, except that the number of encoding conditions was reduced to two, and participants were instructed to fill in the Rosenberg Self-Esteem Scale and Big-Five Inventory. These questionnaires were completed after the memory test, right before the end of the experimental session.

### 5.2.4 Analysis approach

The recognition memory and reaction time data were analysed as in Experiment 1. The effect of individual differences on the SRE was tested with two approaches: 1) an ANOVA with a between-groups factor contrasting those individuals who scored relatively high on the self-esteem or Big-Five questionnaires with those who scored relatively low (achieved by performing a median split on each questionnaire), and 2) between-subject correlations between the self-esteem and Big-Five scores and the size of the SRE for negative, neutral and positive items. Bonferroni's corrections were not applied to the correlations due to prior predictions as stated in the Introduction of this experiment.

## 5.3 Results

Trials with reaction times more or less than two standard deviations from the mean were identified as outliers and excluded from the subsequent analysis. The mean exclusion rates were .03 for the study phase (range .01 - .06; mean for the Self was .05; mean for the Distant Other was .05) and .05 for the test phase (range .03 -.07; mean for the Self was .05; mean for the Distant Other was .06; mean for New items was .04).

### 5.3.1 Recognition memory

Performance in the recognition memory test was measured via Pr values for Recollection and Familiarity for Negative, Neutral, and Positive items (Table 5.1). To reveal the patterns of Pr values across the factors of Valence (Negative vs. Neutral vs. Positive), Reference Person (Self vs. Close Other vs. Distant Other), and Memory Type (Recollection vs. Familiarity), a repeated-measured ANOVA was employed. The results indicated a significant main effect of Reference Person ($F(1, 31) = 38.569$, $\eta_p^2 = .554$, $p < .001$) and a significant interaction between Reference Person and Memory Type ($F(1, 31) = 20.158$, $\eta_p^2 = .394$, $p < .001$). Supplementary analyses to decompose this interaction indicated that the Pr value for the Self was significantly larger than that for the Distant Other, for both Recollection ($F(1, 31) = 60.215$, $\eta_p^2 = .660$, $p < .001$) and Familiarity ($F(1, 31) = 10.832$, $\eta_p^2 = .259$, $p = .002$). The difference was larger for Recollection than Familiarity (Figure 5.1). The main effects of Valence and Memory Type and the interactions between Valence and Reference Person ($F(1.935, 59.991) = 2.506$, $\eta_p^2 = .075$, $p = .092$), between Valence and Memory Type ($F(1.964, 60.882) = .906$, $\eta_p^2 = .019$, $p = .408$) and between Valence, Reference Person and Memory Type ($F(1.930, 59.841) = 1.336$, $\eta_p^2 = .041$, $p = .270$) were not significant..

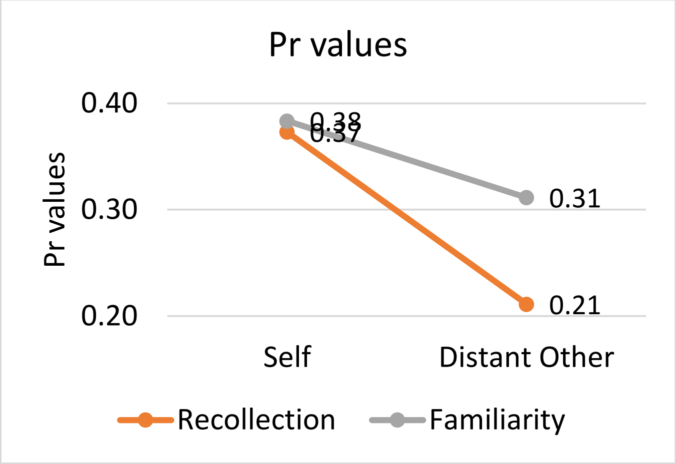

*Figure 5.1. Line graph for Pr values for the Self and Distant Other, separately for recollection and familiarity. Values are collapsed across valences.*

*Table 5.1. Pr values for recollection and familiarity for the Self and Distant Other, separately for each valence.*

| | | Recollection | | | Familiarity | | |
|---|---|---|---|---|---|---|---|
| | | Negative | Neutral | Positive | Negative | Neutral | Positive |
| Self | Mean | .38 | .35 | .38 | .36 | .37 | .43 |
| | SD | .21 | .22 | .24 | .23 | .28 | .31 |
| Other | Mean | .21 | .21 | .21 | .29 | .34 | .30 |
| | SD | .14 | .17 | .20 | .19 | .24 | .26 |

To summarise, a significant SRE was found in this experiment. Participants showed better memory for items associated with themselves than to items associated with a distant other. Both recollection and familiarity contributed to the memory difference, but the difference was larger for recollection. In the next section, recognition memory was contrasted across self-esteem and Big-Five scores to assess individual differences in the SRE.

#### 5.3.1.1 Recognition memory and self-esteem scores

In order to investigate whether recognition memory performance was modulated by self-esteem scores, participants were categorised into high and low groups by the median of the self-esteem scores. Self-esteem group was used as an additional between-subjects factor in the original repeated-measures ANOVA. It was expected that low self-esteem would predict higher memory performance to positive items related to the self. However, no significant interactions between the self-esteem group and any other factors emerged (all Fs < 1.311; detailed statistics please see footnote[2]).

### 5.3.1.2 Recognition memory and scores for the Big-Five traits

The relationship between recognition memory performance and the Big-Five traits was also tested using median-splits for the scores on Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism. The resulting groups were then used as an additional between-participant factor in the original repeated-measures ANOVA.

Analysis of the scores on Openness suggested a significant interaction between Group, Reference Person, Valence and Memory Type (F(1.819, 54.582) = 3.573, $\eta_p^2$ = .106, p = .039). Subsequent analyses on individuals scoring low and high on Openness indicated that the interaction between Reference Person, Valence and Memory Type was marginally significant for low scorers (F(1.737, 24.316) = 3.441, $\eta_p^2$ = .197, p = .054). The interaction was not significant for high scorers (F(1.872, 29.950) = 1.720, $\eta_p^2$ = .097, p = .198). Further analyses in the low Openness group for each emotional valence indicated that the interaction between Self and Memory Type was significant for Neutral (F(1, 14) = 19.168, $\eta_p^2$ = .578, p = .001), but not Negative (F(1, 14) = 3.304, $\eta_p^2$ = .191, p = .091) or Positive (F(1, 14) = 1.026, $\eta_p^2$ = .068, p = .328), items. Follow-up analysis for Neutral items suggested that the difference between Reference Person and Distant Other was significant for Recollection (t(14) = 5.504, p < .001), but not Familiarity (t(14) = .262, p = .797).

Analysis of the scores on Conscientiousness revealed significant interactions between Conscientiousness Group and Memory Type (F(1, 30) = 5.542, $\eta_p^2$ = .156, p = .025). Supplementary analysis separated by Conscientiousness Group suggested that the difference between Recollection and Familiarity was significant for High Group (t(18[3]) = 2.246, p = .037) but not Low Group (t(12) = .638, p = .536). The interaction between Conscientiousness Group, Valence and Reference Person was also significant (F(1.972, 59.166) = 3.716, $\eta_p^2$ = .110, p = .031). Subsequent analysis separated by Conscientiousness Group suggested that the interaction between Valence and Reference Person was significant for High Group (F(1.865, 33.562) = 5.573, $\eta_p^2$ = .236, p = .008) but not Low Group (F(1.905, 22.865) = .347, $\eta_p^2$ = .028, p = .701). Follow-up

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[2] The interactions between Valence and Self-Esteem Group (F(1.847, 55.412) = .470, $\eta_p^2$ = .015, p = .612), between Reference Person and Self-Esteem Group (F(1, 30) = .733, $\eta_p^2$ = .024, p = .399), between Memory Type and Self-Esteem Group (F(1, 30) = .197, $\eta_p^2$ = .007, p = .660), between Valence, Reference Person and Self-Esteem Group (F(1.941, 58.234) = .510, $\eta_p^2$ = .017, p = .598), between Valence, Memory Type and Self-Esteem Group (F(1.978, 59.341) = 1.311, $\eta_p^2$ = .042, p = .277), between Reference Person, Memory Type and Self-Esteem Group (F(1, 30) = .589, $\eta_p^2$ = .019, p = .449) and between Valence, Reference Person, Memory Type and Self-Esteem Group (F(1.930, 57.897) = .384, $\eta_p^2$ = .013, p = .675) were not significant.

[3] Median-split of Conscientiousness resulted in 13 participants in the low group and 19 participants in the high group.

analysis suggested that for High Group, the differences between Self and Distant Other were significant for Valences of Negative (.38 vs. .25, difference .13; t(18) = 3.613, p = .002), Neutral (.38 vs. .27, difference .11; t(18) = 4.655, p < .001) and Positive (.44 vs. .28, difference .16; t(18) = 4.270, p < .001), with the difference of Positive (.16) seemed larger than the difference of Negative (.13) and Neutral (.11) items.

The analyses did not reveal further significant interactions across individuals scoring low and high with conscientiousness[4], extraversion[5], agreeableness[6] or neuroticism[7].

## 5.3.2 Reaction times

### 5.3.2.1 Study phase

The reaction times (shown in Table 5.2) were analysed using a repeated-measures ANOVA with factors of Reference Person (Self vs. Distant Other) and Valence (Negative vs. Neutral vs. Positive). The results indicated that participants took longer to make a judgment about a Distant Other than to the Reference Person (1562 ms vs 1503 ms; F(1, 31) = 11.082, $\eta_p^2$ = .263, p = .002). The main effect of Valence (F(1.844, 57.156) = 2.536, $\eta_p^2$ = .076, p = .092) and the interaction between Reference Person and Valence (F(1.770, 54.873) = 3.048, $\eta_p^2$ = .090, p = .062) were not significant.

*Table 5.2. Reaction times (in ms) for the Self, Close Other and Distant Other during the study phase, separately for each emotional valence.*

| | Emotion | | |
|---|---|---|---|
| | Negative | Neutral | Positive |

---

[4] The interactions between Conscientiousness Group and Valence (F(1.856, 55.686) = .433, $\eta_p^2$ = .014, p = .636), between Conscientiousness Group and Reference Person (F(1, 30) = .487, $\eta_p^2$ = .016, p = .496), between Conscientiousness Group, Valence and Memory Type (F(1.959, 58.768) = .529, $\eta_p^2$ = .017, p = .588), between Conscientiousness Group, Memory Type and Reference Person (F(1, 30) = .707, $\eta_p^2$ = .023, p = .407) and between Conscientiousness Group, Valence, Memory Type and Reference Person (F(1.929, 57.859) = .563, $\eta_p^2$ = .018, p = .566) were not significant.

[5] The interactions between Extraversion Group and Valence (F(1.855, 55.655) = .258, $\eta_p^2$ = .009, p = .757), between Extraversion Group and Memory Type (F(1, 30) = 3.062, $\eta_p^2$ = .093, p = .090), between Extraversion Group and Reference Person (F(1, 30) = .200, $\eta_p^2$ = .007, p = .658), between Extraversion Group, Valence and Memory Type (F(1.963, 58.889) = .659, $\eta_p^2$ = .022, p = .518), between Extraversion Group, Valence and Reference Person (F(1.941, 58.237) = 1.979, $\eta_p^2$ = .062, p = .149), between Extraversion Group, Memory Type and Reference Person (F(1, 30) = .917, $\eta_p^2$ = .0308, p = .346) and between Extraversion Group, Memory Type and Reference Person (F(1.889, 56.680) = 2.334, $\eta_p^2$ = .072, p = .109) were not significant.

[6] The interactions between Agreeableness Group and Valence (F(1.736, 52.094) = 2.710, $\eta_p^2$ = .083, p = .083), between Agreeableness Group and Memory Type (F(1, 30) = .538, $\eta_p^2$ = .018, p = .538), between Agreeableness Group and Reference Person (F(1, 30) = 1.245, $\eta_p^2$ = .040, p = .273), between Agreeableness Group, Valence and Memory Type (F(1.974, 59.231) = .841, $\eta_p^2$ = .026, p = .446), between Agreeableness Group, Valence and Reference Person (F(1.899, 56.984) = 1.369, $\eta_p^2$ = .044, p = .262), between Agreeableness Group, Memory Type and Reference Person (F(1, 30) = .465, $\eta_p^2$ = .015, p = .500), and between Agreeableness Group, Memory Type and Reference Person (F(1.937, 58.096) = .705, $\eta_p^2$ = .023, p = .494).

[7] The interactions between Neuroticism Group and Valence (F(1.852, 55.548) = .004, $\eta_p^2$ = .004, p = .864), between Neuroticism Group and Memory Type (F(1, 30) = 1.217, $\eta_p^2$ = .039, p = .279), between Neuroticism Group and Reference Person (F(1, 30) = 1.217, $\eta_p^2$ = .039, p = .279), between Neuroticism Group, Valence and Memory Type (F(1.972, 59.145) = .738, $\eta_p^2$ = .024, p = .481), between Neuroticism Group, Valence and Reference Person (F(1.935, 58.057) = .040, $\eta_p^2$ = .001, p = .957), between Neuroticism Group, Memory Type and Reference Person (F(1, 30) = .609, $\eta_p^2$ = .020, p = .441) and between Neuroticism Group, Valence, Memory Type and Reference Person (F(1.931, 57.919) = .224, $\eta_p^2$ = .007, p = .792).

|  |  |  |  |  |
|---|---|---|---|---|
| Self | Mean | 1480 | 1544 | 1488 |
|  | SD | 262 | 342 | 284 |
| Distant Other | Mean | 1572 | 1562 | 1554 |
|  | SD | 313 | 296 | 275 |

#### 5.3.2.2 Test phase

During the recognition memory test, participants took longer to make judgments about items associated with Other than the Self for both Remember and Know responses (mean reaction times: Self Remember = 1134 ms; Self Know = 1195 ms; Other Remember = 1201 ms; Other Know = 1232 ms). The difference between the Self and Other conditions seemed larger for Remember responses than Know responses (67 ms vs. 38 ms). A repeated-measures ANOVA employing factors of Reference Person (Self vs. Distant Other) and Memory Type (Remember vs. Know) confirmed this observation. A significant main effect of Self indicated that participants took longer to make judgments about a Distant Other than the Self (F(1, 30) = 16.001, $\eta_p^2$ = .348, p < .001). The interaction between Reference Person and Memory Type was also significant (F(1, 29) = 4.401, $\eta_p^2$ = .128, p = .044). Supplementary paired-sample t-tests indicated that the difference between reaction times for Self and Distant Others was significantly different for Remember responses (t(31) = -4.514, p < .001), but not for Know responses (t(30[8]) = -1.308, p = .201). The main effect of Memory Type was not significant (F(1, 30) = 1.548, $\eta_p^2$ = .049, p = .223).

### 5.3.3 Correlations

The results of the correlational analyses below are separated in three sections: the correlations between individual scales, the correlations between the scales and encoding judgements and the correlations between the scales and the sizes of the SRE.

#### 5.3.3.1 Correlations between individual scales

The correlations between the Big-Five personality traits (Extraversion, Agreeableness, Openness, Conscientiousness and Neuroticism) and Self-Esteem are reported in Table 5.3. The results showed significant positive correlations between Self-Esteem and Extraversion (r(32) = .408, p = .020; Figure 5.2) and Self-Esteem and Conscientiousness (r(32) = .370, p = .037). Negative correlations were found between Self-Esteem and

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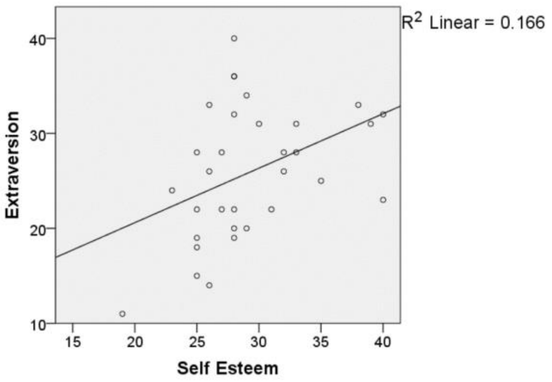
[8] One of the participants in this experiment did not give any Know responses in the Distant Other condition.

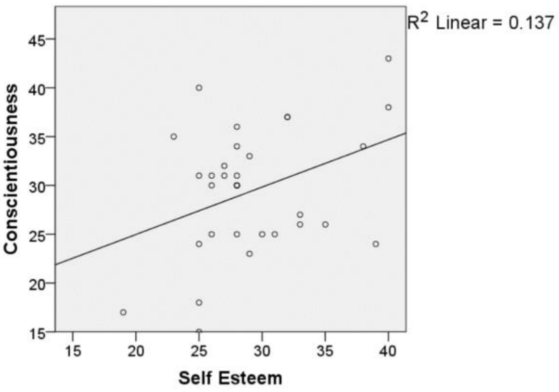
Neuroticism (r(32) = -.395, p = .025) and between Extraversion and Neuroticism (r(32) = -.395, p = .025). No other significant correlations were found between the scales[9].

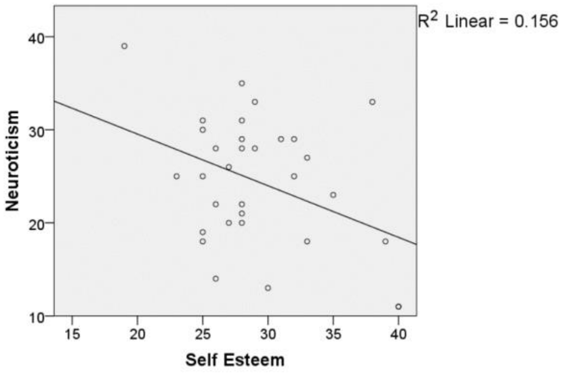
*Table 5.3. Correlations between the Big-Five personality traits and Self-Esteem.*

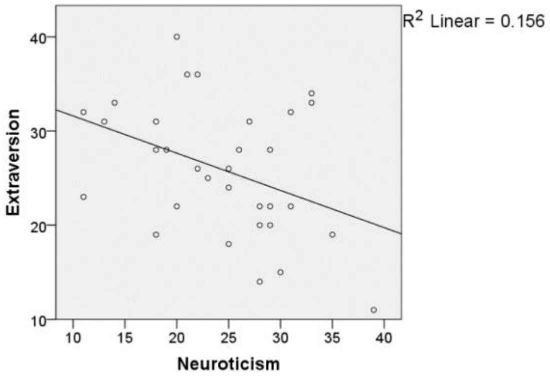
| | Correlations | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1. Extraversion | 1.00 | | | | | |
| 2. Agreeableness | -.048 | 1.00 | | | | |
| 3. Conscientiousness | .294 | .341 | 1.00 | | | |
| 4. Neuroticism | -.395* | -.169 | -.227 | 1.00 | | |
| 5. Openness | -.155 | -.078 | -.317 | .167 | 1.00 | |
| 6. Self-Esteem | .408* | .193 | .370* | -.395* | -.026 | 1.00 |

* p < .05









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[9] The correlations between Self-Esteem and Agreeableness (r(32) = .193, p = .290), between Self-Esteem and Openness (r(32) = -.260, p = .890), between Extraversion and Agreeableness (r(32) = -.480, p = .794), between Extraversion and Conscientiousness (r(32) = .294, p = .102), between Extraversion and Openness (r(32) = -.155, p = .396), between Agreeableness and Conscientiousness (r(32) = .341, p = .056), between Agreeableness and Neuroticism (r(32) = -.169, p = .255), between Agreeableness and Openness (r(32) = -.078, p = .670), between Conscientiousness and Neuroticism (r(32) = -.227, p = .212), between Conscientiousness and Openness (r(32) = -.317, p = .077) and between Neuroticism and Openness (r(32) = .167, p = .361) were not significant.

Figure 5.2. Scatter plots and linear regression lines of significant inter-scale correlations. Top left: Extraversion vs. Self-Esteem; Top right: Conscientiousness vs. Self-Esteem; Bottom left: Neuroticism vs. Self-Esteem; Bottom right: Extraversion vs. Neuroticism.

#### 5.3.3.2 Correlations between the scale scores and the encoding responses

In order to reveal individual differences in the way items with different valences were processed during the encoding task, the proportions of responses "consistent" with the Self and a Distant Other were calculated for each valence (Negative-diff, Neutral-diff and Positive-diff). Higher difference scores represent participants who rated themselves as more consistent on that attribute than a Distant Other. The results suggested significant positive correlations (Figure 5.3) between Extraversion and Positive-diff (r(32) = .353, p = .047) and between Neuroticism and Negative-diff (r(32) = .400, p = .023). No other significant correlations were found[10].

To summarise, participants with higher Extraversion scores were more likely to rate themselves as consistent with positive items than distant others. Participants with higher Neuroticism scores were more likely to rate themselves as consistent with negative adjectives than distant others.

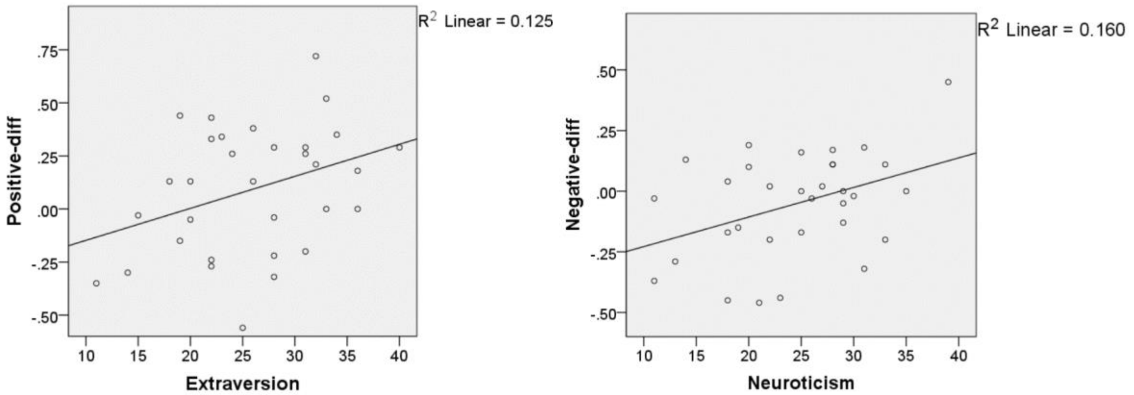

*Figure 5.3. Significant correlations between questionnaire scores and encoding task responses. Left: Extraversion scores plotted against the difference between the proportions of positive adjectives rated as consistent with the Self versus a Distant Other;*

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[10] The correlations between Negative-diff and Extraversion (r(32) = -.344, p = .054), between Negative-diff and Agreeableness (r(32) = -.245, p = .177), between Negative-diff and Conscientiousness (r(32) = -.117, p = .525), between Negative-diff and Openness (r(32) = .023, p = .899), between Negative-diff and Self-Esteem (r(32) = -.313, p = .081), between Neutral-diff and Extraversion (r(32) = .196, p = .283), between Neutral-diff and Agreeableness (r(32) = .016, p = .932), between Neutral-diff and Conscientiousness (r(32) = -.172, p = .347), between Neutral-diff and Neuroticism (r(32) = .054, p = .770), between Neutral-diff and Openness (r(32) = -.070, p = .704), between Neutral-diff and Self-Esteem (r(32) = -.093, p = .613), between Positive-diff and Agreeableness (r(32) = .117, p = .523), between Positive-diff and Conscientiousness (r(32) = .263, p = .145), between Positive-diff and Neuroticism (r(32) = -.055, p = .767), between Positive-diff and Openness (r(32) = -.107, p = .559) and between Positive-diff and Self-Esteem (r(32) = .235, p = .196) were not significant.

*Right: Neuroticism scores plotted against the difference between the proportions of negative adjectives rated as consistent with the Self versus a Distant Other.*

#### 5.3.3.3 Correlations between scale scores and memory performance

To reveal correlations between the scale scores and memory performance, the difference between the recollection-related Pr of items associated with the Self and a Distant Other was calculated for Negative (Negative-R-Pr-diff), Neutral (Neutral-R-Pr-diff) and Positive (Positive-R-Pr-diff) items. These values represent the size of the SRE for each valence and the difference calculated. It was predicted that lower self-esteem scores would be correlated with larger SREs for positive items. However, no significant correlations were found[11].

### 5.3.4 Summary

In this experiment, participants remembered items related to the self better than items related to a distant other, as is typically found. The difference between the self and a distant other was significant for both recollection and familiarity, although it was larger for the former. During encoding, participants took a longer time to make a judgment about a distant other than the self. During retrieval, a similar pattern was found for recollection but not familiarity: participants took longer to make a Remember judgment to a distant other than to the self.

It was predicted that self-esteem scores would show a negative correlation with the SRE for positive items. That is, lower self-esteem scores would coincide with larger SREs for attributes that have a positive emotional valence. However, neither the correlational analyses nor medium-split ANOVAs revealed SRE differences as a function of self-esteem scores. There were trends in the data that participants with higher self-esteems had higher extraversion and conscientiousness, and lower neuroticism, scores. Participants with low openness scores showed a larger SRE for neutral items for recollection but not familiarity. Furthermore, participants with higher extraversion scores rated themselves as more consistent with positive traits than a distant other. Participants with high Conscientiousness scores showed a larger SRE to positive items than both

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[11] The correlations between Negative-R-Pr-diff and Extraversion (r(32) = .129, p = .480), between Negative-R-Pr-diff and Agreeableness (r(32) = .113, p = .537) , between Negative-R-Pr-diff and Conscientiousness (r(32) = .050, p = .785) , between Negative-R-Pr-diff and Neuroticism (r(32) = .011, p = .954) , between Negative-R-Pr-diff and Openness (r(32) = .229, p = .207) , between Negative-R-Pr-diff and Self-Esteem (r(32) = .052, p = .777), between Neutral-R-Pr-diff and Extraversion (r(32) = -.144, p = .432), between Neutral-R-Pr-diff and Agreeableness (r(32) = -.056, p = .760), between Neutral-R-Pr-diff and Conscientiousness (r(32) = -.096, p = .601), between Neutral-R-Pr-diff and Neuroticism (r(32) = -.041, p = .825), between Neutral-R-Pr-diff and Openness (r(32) = -.166, p = .365), between Neutral-R-Pr-diff and Self-Esteem (r(32) = -.227, p = .211), between Positive-R-Pr-diff and Extraversion (r(32) = .112, p = .540), between Positive-R-Pr-diff and Agreeableness (r(32) = .214, p = .240), between Positive-R-Pr-diff and Conscientiousness (r(32) = .306, p = .089), between Positive-R-Pr-diff and Neuroticism (r(32) = .080, p = .663), between Positive-R-Pr-diff and Openness (r(32) = -.023, p = .899) and between Positive-R-Pr-diff and Self-Esteem (r(32) = -.218, p = .230) were not significant.

negative and neutral items, regardless recollection and familiarity. Participants with higher neuroticism scores instead rated themselves as more consistent with negative traits.

## 5.4 Discussion

Experiment 3 was designed to investigate individual differences in the sizes of the SRE in the context of comparing the self with a familiar but distant other, though the closeness of the distant other was not measured directly. Participants encoded negative, neutral and positive personality traits by incidentally judging whether the traits describe themselves or a distant other. They then performed a memory test with the Remember/Know procedure. After the memory test, individual differences among the participants were measured via subjective questionnaires of self-esteem and the Big-Five personality traits. It was predicted that participants with low self-esteem should show a higher SRE for positive items than participants with high self-esteem. It has been shown that positive items can be better integrated into the self-schema of low self-esteem individuals, resulting in a deeper encoding (Jones & Brunell, 2014).

In line with the findings of Experiments 1 and 2, a significant SRE was found for the overall memory performance. Interestingly, the data of this experiment also suggested that the SRE is larger for recollection than for familiarity. This finding is consistent with previous studies suggesting that SR encoding benefits memory by associating information with more contextual details (e.g., Conway & Dewhurst, 1995; Leshikar et al., 2015) or other source information (Dulas et al., 2011; Durbin et al., 2017). The larger SRE for recollection than familiarity is not completely consistent with the findings in Experiment 1, however, which suggested an overall SRE regardless of recollection and familiarity. The difference might be due to the fact that the encoding conditions in the current experiment were restricted to the self and a distant other, as compared to the additional close other condition in Experiment 1. Studies have suggested that recollection is a more attention-demanding process compared to familiarity. When attention is disrupted during encoding, this may affect recollection more than familiarity (Gardiner & Parkin, 1990; Parkin, Gardiner, & Rosser, 1995). It is possible that the reduction of switching between encoding conditions in this experiment decreased cognitive load and provided participants with attentional resources to encode items related to themselves. This idea is supported by the fact that recollection was higher for the self in the current experiment compared to that in Experiment 1 (.37 vs. .33), while the recollection for the distant other was lower (.21 vs. .26). It thus seems that the SRE for recollection has been amplified in this experiment compared to Experiment 1, an effect that was not found for familiarity.

Surprisingly, no significant correlations were found between the size of the SRE and scores on the self-esteem and Big-Five trait questionnaires, regardless of emotional valence of an item. These null results are not consistent with previous findings, which indicated significant memory benefits for positive items for low self-esteem individuals (Jones & Brunell, 2014; Zhang et al., 2013). One possibility is that individuals with low self-esteem did engage in deeper processing for positive items during encoding, but that this did not affect memory retrieval. If this is the case, then the reaction times during encoding might be expected to be longer for low self-esteem participants when processing positive items in relation to themselves. However, reaction times did not show such a pattern ($p = .586$). This does not provide support for the deeper encoding account. An alternative account for the null result is that the sample size in the experiment was not sufficient to have the statistical power to detect individual differences in the SRE.

Disregarding the SRE, there were significant correlations between the self-esteem and Big-Five questionnaires themselves. Self-esteem scores were positively correlated with extraversion and conscientiousness scores, and negatively with neuroticism scores. Interestingly, these findings are consistent with previous studies investigating the correlation between the two scales. It has been found that the more extroverted participants are, the more consistently they rate themselves as having positive traits than a distant other (Robins et al., 2001). In this experiment, it was also found that the more neurotic participants are, the more consistently they rated themselves with negative traits. These patterns might suggest that participants were keeping their self-image consistent across stages of the experiment. They were not aware that they would be completing the subjective questionnaires while making trait judgments during encoding. Such finding is consistent with the concept that personality traits, unlike mood, is relatively stable across time (Caspi & Roberts, 2001; Caspi, Roberts, & Shiner, 2005). The correlation between the encoding preferences and extraversion score may also suggest that the self-positivity bias, the trend to judge oneself as more positive than a third-party person (Leary, 2007; Zhang et al., 2013), was modulated by individual differences. Instead of considering the correlation is a result of keeping positive self-image, the correlations between the questionnaire scores and encoding judgments can also be alternatively interpreted as arising from characteristics of distant others, instead of differences due to the self. However, this is unlikely because the distant others in the experiment were randomly assigned. Even if it is possible that different distant others may have different personality characteristics and result in different responses from the participants, assigning the distant others randomly should have eliminated any systematic differences.

Another finding in the current experiment worth noting is that for participants with low openness scores, there was a trend that they recollected neutral items related to themselves better than neutral items related to a distant other. This finding was restricted to recollection and not found for familiarity and may reflect an interaction between personality traits, episodic memory and emotion. The reason for this finding is not clear, and the reaction times during encoding did not show differences between neutral items related to themselves and a distant other ($p = .216$). One speculation is that individuals with low openness scores are less curious than individuals with high openness scores about having new experiences (John & Srivastava, 1999). This may result in fewer associations being generated for a distant other during encoding. Decisions about adjectives may rely on pre-existing knowledge of a fictional character in memory instead of retrieving relevant episodes and performing evaluations on the fly. On the other hand of neutral items, for emotional items, the participants may be motivated to generate associations for themselves and a distant other due to more attentional resource allocated to emotional items (Nairne, 2010) regardless the openness, hence the recollection of emotional items were not modulated by individual differences. Participants with high conscientiousness scores showed a larger SRE for positive items than both negative and natural items. This might be due to the self-construct of the participants with high conscientiousness scores shared more mutual elements of the positive adjectives used in this experiment than negative and neutral adjectives. This speculation is in line with the fact that in the big-five questionnaire used in this experiment, high conscientiousness scores were from descriptions directly linked to positive personality traits, for example, ‘thorough’, ‘reliable’ and ‘efficient’. In this case, when participants encoded the adjective traits during encoding, the overlap between the self-construct and the positive traits might facilitate the encoding of positive items referenced to themselves more than to items referenced to a distant other, and yet this overlap was not the case to negative and neutral items.

Nevertheless, the current experiment may suffer from two potential methodological issues. First, the analysis of individual differences and the SRE was based on multiple comparisons across the experiment, though prior predictions were made. This issue may lead to false-positive results (Smith, Levine, Lachlan, & Fediuk, 2002). Second, the sample size of this experiment was not particularly comparable compared to relevant studies (e.g., $n = 201$ in Jones and Brunell (2014) or $n = 50$ in Pinter et al. (2011)), which may lead to either false positive or false negative results due to lack of sufficient power to detect the effects of interests (Button et al., 2013). More details of these issues are discussed in the General Discussion of this thesis.

To summarise, the current experiment addressed whether individual differences affect the SRE in the context of comparing the self with a distant other. The results suggested no significant correlations between individual differences and the emotional SRE.

Experiments 1 to 3 were designed to address the first research question of the thesis: the effect of closeness to others on the SRE. Across the three behavioural experiments, better memory and contextual details were found for the self than both close and distant others. This finding suggested that subjective closeness to other person cannot exclusively explain the presence of the SRE, and the factor underlying the SRE during encoding and retrieval has not yet conclusive. In the next two chapters, the brain activity during self- and other-referenced encoding and retrieval will be investigated to answer the second research question of the thesis.

# Chapter 6. Experiment 4: self-reference effect with the self and a close other using ERP and oscillatory analysis

## 6.1 Introduction

Experiments 1, 2 and 3 described in the previous chapters addressed the first question of this thesis, namely what the role of closeness to others is in the SRE. This question was addressed with behavioural studies, using the Remember/Know and source memory procedures and by considering individual differences in the SRE. The next two chapters describe Experiments 4 and 5, which addressed the second question of this thesis. Using EEG, the experiments investigate the electrophysiological brain activities that are associated with encoding and retrieving information regarding oneself. In Experiment 4, these activities are addressed by comparing the self with a close other. In Experiment 5, the comparison is instead between the self and a distant other. Comparing the self with two types of others in separate experiments suits the EEG technique in that a better signal quality can be obtained by avoiding lengthy experimental sessions yet obtaining sufficient numbers of trials. The two EEG experiments also revolve around the issue of closeness to others.

The two EEG experiments were carried out with similar procedures as the behavioural experiments reported in the previous chapters of the thesis. This was done to allow useful comparisons across studies. Generally speaking, the previous three experiments always showed better memory performance for the self than both a close and distant other with equivalent levels of familiarity (Experiments 1 and 2). This may reflect that the encoding and retrieval of information pertaining to the self rely on distinct mechanisms as compared with processing of information about others. This speculation is in line with previous neuroimaging studies on the SRE. Studies have suggested that distinct brain regions (e.g., mPFC) are involved in self-referenced encoding (Kelley et al., 2002) and retrieval (Bergström et al., 2015; D'Argembeau, Collette, et al., 2005; de Caso et al., 2017; Gutchess, Kensinger, Yoon, et al., 2007; Leshikar & Duarte, 2014).

Compared to hemodynamic imaging studies, the SRE has attracted less attention in electrophysiological studies. The limited number of studies (Dulas et al., 2011; Mu & Han, 2010) do not always support the idea that the encoding and retrieval of self-referenced information rely on distinct neural populations. Specifically, Dulas et al. (2011) used ERPs to investigate the SRE in recognition memory. They found that the mid-frontal and left parietal old/new effects typically associated with familiarity and recollection (Rugg & Curran, 2007; Vilberg & Rugg, 2007) did not differ between information encoded in relation to the self or a semantic control task. Instead, it was found that the mid-frontal effect was affected by ageing, with the older group showing a diminished mid-frontal effect than the younger group. With similar patterns found between the self-referencing and control conditions, these data do not imply that the two types of encoding rely on distinct neural populations. In contrast to this idea, a previous study that used oscillatory brain responses to investigate the SRE showed that specific neural mechanisms are found for self-referencing than other types of encoding tasks (Mu & Han, 2010). It was found that compared to other-referencing and a visual control task, self-referencing during encoding was associated with theta and alpha power increases and beta power decreases. Additionally, the left-frontal theta power increase during encoding was positively correlated with the size of the behavioural SRE during retrieval. The inconsistent findings across studies may be due to different types of activities being captured by ERPs and oscillatory activities or, alternatively, to the different experimental designs. Importantly, however, there is a lack of studies that employ electrophysiological brain activities to understand the role of the self in episodic memory. The current experiment addresses this gap by considering ERP and oscillatory responses during various stages of episodic memory, including the period before encountering a to-be-encoded stimulus, the period thereafter, and the later period of memory retrieval.

Based on the previous findings in this thesis and in the literature, it is hypothesised that self-referenced encoding engage more elaborative and organisational processes due to access to self-schema compared to other-referenced encoding (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997). Items related to the self may accordingly be remembered better than items related to a close other, which only involve organisational processing (Symons & Johnson, 1997). The brain activities during the interval before a to-be-encoded event is encountered may reflect the preparatory processes in response to a cue that indicates whether an upcoming adjective should be processed in relation to the self or a close other. To my knowledge, there have not been any previous studies that have investigated preparatory brain activities in relation to self-referenced encoding. It is speculated that the self may elicit a larger pre-stimulus subsequent ERP effect than a close other due to decisions about the self mobilising additional top-down control and attention processes (Fan et al., 2013; Ninomiya et al., 1998; Tacikowski & Nowicka, 2010). A difference may also be found in oscillatory analyses given that the self has been related to theta and alpha power increases reflecting inhibitory top-down control on irrelevant episodic details (Fell et al., 2011).

During post-stimulus encoding, the self may elicit a larger SME than a close other because of the additional cognitive processes employed by the self. The subsequent memory effect may be affected by the self enhancing semantic processing of the materials (Friedman & Trott, 2000; Otten & Rugg, 2001; Otten et al., 2007; Paller & Wagner, 2002) or by additional attentional processes that facilitate memory encoding

(Duarte et al., 2004; Otten et al., 2007). The conceptual enhancement of the self during encoding may also affect the oscillatory activities in the theta, alpha and beta bands because it has been shown that these bands are sensitive to the conceptual properties of to-be-encoded materials (e.g., Hanslmayr & Staudigl, 2014; Hanslmayr et al., 2012).

In the previous experiments reported in this thesis, it was shown that decisions about the self received a higher contribution from both recollection and familiarity than decisions about a close other. It is accordingly predicted for the current experiment that effects of the self will be found for brain activities related to recollection and familiarity during retrieval. For familiarity, retrieving information processes in relation to the self should give rise to larger mid-frontal old/new effects (Azimian-Faridani & Wilding, 2006; Curran, 2000; Woodruff et al., 2006). For recollection, the left-parietal (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996) and late posterior negative (Herron, 2007; Johansson & Mecklinger, 2003) old/new effects are expected to be larger for the self-referential condition. Successful memory retrieval of self-referential information may also be associated with increases in theta power over left-frontal scalp sites, which may reflect cortical reinstatement of relevant memory representations (Guderian & Duzel, 2005; Hanslmayr et al., 2016; Hanslmayr & Staudigl, 2014).

## 6.2 Methods

### 6.2.1 Participants

Thirty-three right-handed, native English speakers volunteered to participate in the experiment (mean age 26 years old, range 18-40 years old; 16 female). All participants had normal or corrected-to-normal vision and reported no history of neurological or psychological illness. Written consent forms were acquired before individuals participated in the experiment. They were paid £7.50 per hour for their participation. The experimental procedures were approved by the University College London Research Ethics Committee.

### 6.2.2 Materials

In addition to the 264 English personality trait adjectives used in Experiments 1 and 2, another 72 items were included as the materials for the two EEG experiments to boost trial numbers to each condition. The inclusion resulted in a total of 336 English personality trait adjectives. Three sets of 112 adjectives each were randomly selected from the materials pool with word frequencies, word lengths, syllable numbers, mean valence and mean arousal levels controlled across the three sets (all Fs < 1.4). The sets were rotated across participants to create different study and test lists. For each participant, two of the three sets were used in the study phase, one set for the Self condition and one set for the Close Other condition. The list of items in the test phase was created by including the third list. The test list accordingly consisted of 224 old items and 112 new items. The adjectives were rotated across the Old-Self, Old-Close Other and New conditions across participants. The words were presented in written format in black against a 50% grey background (visual angle was about 2.5 degrees horizontally and 1 degree vertically). An additional 12 adjectives were used for the practice.

### 6.2.3 Procedure

The experimental procedure was similar to that of Experiments 1 and 2, except that the encoding conditions consisted of the Self and a Close Other. The participants were initially instructed to give the names of six people that they felt close to, name their relationship to these people and rate the people on the following four questions using a 10-point scale: (1) how well do you know the person, (2) how well do you think the person knows you, (3) how close do you feel you are to the person, and (4) how close does the person feel to you (1: not well at all, almost like a stranger; 10: very well, almost like myself). The person with the highest total score was then assigned as a participant’s close other.

### 6.2.4 EEG acquisition

EEG signals were recorded from 41 scalp sites using silver/silver-chloride electrodes embedded in an elastic cap according to an equidistant montage (Montage 10, see https://www.easycap.de/wordpress/wp-content/uploads/2018/02/Easycap-Equidistant-Layouts.pdf). Two additional electrodes were attached to the left and right mastoids as a basis for offline re-referencing. Four additional electrodes were attached to record eye-movement related activities. Vertical eye movements were picked up by two electrodes placed above and below the right eye. Horizontal eye movements were recorded via two electrodes placed at the outer canthi. EEG signals were referenced to a midline frontal scalp site (site 2) during recording. Impedance of the electrodes was kept below 5 kΩ across sessions. Signals were amplified by a Brain Vision BrainAmp DC amplifier with sampling rate of 1000 Hz (16-bit resolution) and an analogue band-pass filter between 0.016 and 250 Hz. During the recording, an additional digital low-pass filter of 70 Hz was applied to the signals.

### 6.2.5 ERP analysis

The MATLAB-based EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) toolboxes were used to carry out signal pre-processing for ERP and oscillatory analysis. Offline, EEG signals were down-sampled to 250 Hz with a digital low-pass filter at 20 Hz (48 dB/Oct roll-off). The continuous data were segmented into epochs of 2100 ms duration, starting 100 ms before cue/adjective onset until 2000 ms thereafter. The 100 ms intervals prior to cue/adjective onsets were used as baselines (cf. Galli et al., 2011; M. J. Gruber & Otten, 2010). The signals were re-referenced to the average of the two mastoids and the signal of the online reference (site 2) was reinstated. Ocular artefacts were removed using Independent Component Analysis (Bell & Sejnowski, 1995; Delorme & Makeig, 2004; Hoffmann & Falkenstein, 2008) implemented in the EEGLAB. Components of eye movements were identified manually according to the correlation between the activations of the components and EOG channels. Epochs in which activity at any time point exceeded -100 or 100 µV were automatically marked as potential artifacts, but only those epochs containing drifting, eye movements or muscle activities were excluded. At the end of the pre-processing, epochs were averaged for each participant, experimental condition and electrode site. To obtain sufficient numbers of trials for the subsequent memory analyses, adjectives were classified as ‘forgotten’ when they attracted either a Know or New response during the test phase. Adjectives were classified as ‘remembered’ when they gave rise to a Remember response. For the comparison in the test phase, the Hit condition was formed from old adjectives attracting Remember responses and the Correct Rejection condition was formed from new adjectives attracting New responses. The ERPs for items receiving Know judgments were not considered due to insufficient trial numbers. Only participants with 15 or more trials in each condition of interest were considered further (mean, standard deviation (SD), maximum and minimum trials numbers for each condition are listed in Table 6.1). Nine out of the 33 participants had to be excluded from the study and test phase analyses because of insufficient trials, resulting in a sample size of 24.

*Table 6.1. Trial numbers for each condition of the ERP analysis, Experiment 4.*

| Condition | | | Mean | SD | Max | Min |
|---|---|---|---|---|---|---|
| Pre-stimulus | Remember | Self | 45 | 14 | 78 | 24 |
| | | Close Other | 38 | 13 | 60 | 17 |
| | Forgotten (Miss + Know) | Self | 51 | 14 | 76 | 22 |
| | | Close Other | 58 | 16 | 88 | 20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Post-Stimulus | Remember | Self | 42 | 15 | 78 | 18 |
| | | Close Other | 36 | 12 | 60 | 17 |
| | Forgotten (Miss + Know) | Self | 51 | 16 | 86 | 17 |
| | | Close Other | 61 | 25 | 149 | 22 |
| Retrieval | Remember | Self | 46 | 15 | 84 | 26 |
| | | Close Other | 39 | 15 | 78 | 16 |
| | Correct Rejection | | 59 | 24 | 97 | 19 |

### 6.2.6 Oscillatory analysis

The EEGLAB toolbox (Delorme & Makeig, 2004) was used to process the EEG data and time-frequency analyses. The EEG signal was down-sampled to 250 Hz with a band-pass filter between 0.5 and 50 Hz (48 dB/Oct roll-off). The high-cut frequency is higher than that for ERP analysis to maintain the information in the frequency bands of interests of the oscillation analysis. The signal was segmented into epochs from 600 ms before cue onsets to 4200 ms thereafter for the study phase, and from 600 ms before adjective onsets to 3500 ms thereafter for the test phase. Only the intervals between 0-3600 ms during study and 0-2700 ms during test were taken into account to avoid the edge effect (Torrence & Compo, 1998). The epoch lengths were chosen to cover the entire 1500 ms cue interval and 2100 ms after adjective onsets during the study phase, and the 2700 ms period after adjective onsets during the test phase. Baseline correction in the time-domain was performed using the mean signal in the 600 ms period before event onsets. The signals were re-referenced to the two mastoids and the online reference (site 2) was reinstated. Trials in which EEG activity exceeded three standard deviations from the mean on an electrode or five standard deviations across all electrodes were excluded from the analyses (cf. M. J. Gruber et al., 2013). Blinks and eye movements were removed via Independent Component Analysis (Bell & Sejnowski, 1995; Delorme & Makeig, 2004; Hoffmann & Falkenstein, 2008) with the same procedure as ERP.

The time-frequency transformation was carried out with Morlet wavelets with 4 cycles and a moving time window of 20 ms in the 0-3600/0-2700 ms time windows. The time-frequency transformation was done in steps of 1 Hz from 4 to 30 Hz. Each frequency value represents the central frequency of each 1 Hz range (e.g., 4 Hz represents range of 3.5-4.5 Hz). Baseline corrections in the frequency-domain were not applied because the analyses focus on differences between conditions rather than absolute values (cf. Fell et al., 2011; M. J. Gruber et al., 2013). Brain activities for each participant were contrasted as a function of the reference person (Self vs. Close Other in Experiment 4 and Self vs. Distant Others in Experiment 5) and memory category (for the study phase:

subsequently remembered vs. subsequently forgotten; for the test phase: remembered vs. correct rejection). Only participants with more than 14 trials in any of the conditions of interests were included in the statistical analyses (mean, standard deviation (SD), maximum and minimum trials numbers for each condition are listed in Table 6.2). Nine out of the 33 participants were excluded from the statistical analysis due to this reason. Trials included in the ERP and time-frequency analysis were 92% and 84% overlapped for encoding and retrieval data.

Inter-trial permutation tests were used to statistically test the power changes across the conditions of interest. The mean power value was calculated for each frequency band, time window, electrode, trial and participant. The 3600 and 2400 ms time windows for study and test phases were collapsed into 12 and 8 time windows of 300 ms each. These mean values were submitted to permutation tests for each time window and electrode to reveal significant differences between conditions. The statistical tests were based on M. J. Gruber et al. (2013), who performed a three step procedure. In the first step, two-tailed t tests were applied to the mean power values of the relevant conditions for each frequency band, time window and electrode. In the second step, the same data set was separated into two random pseudo conditions and submitted to another t test, and this procedure was repeated 1000 times. In the third step, the t values obtained in the second step were sorted in ascending order to determine the t values of the 25th and 975th permutation, which served as the critical t values with a .05 alpha rate to reject the null hypothesis of equal power in the two conditions. With 41 electrodes, it is expected that this procedure may result in Type I Errors on 2.05 electrodes (41 electrodes x .05) in each time window. Only significant effects extending across three or more electrodes were therefore considered. To further decrease the likelihood of detecting false positive effects, only significant effects that spanned across at least two time windows (600 ms at least) were considered for interpretation. The statistical analyses considered three bands of interests: Theta (4-7 Hz), Alpha (8-12 Hz) and Beta (13-30 Hz).

*Table 6.2. Trial numbers for each condition of the time-frequency analysis, Experiment 4.*

| Condition | | | Mean | SD | Max | Min |
|---|---|---|---|---|---|---|
| Encoding | Remember | Self | 46 | 14 | 77 | 24 |
| | | Close Other | 39 | 14 | 70 | 15 |
| | Forgotten (Miss + Know) | Self | 49 | 14 | 72 | 20 |
| | | Close Other | 55 | 14 | 82 | 27 |
| Retrieval | Remember | Self | 47 | 14 | 79 | 21 |
| | | Close Other | 41 | 15 | 71 | 16 |

| | | | | |
|---|---|---|---|---|
| Correct Rejection | 62 | 18 | 89 | 24 |

## 6.3 Results

Trials with reaction times more or less than two standard deviations from the mean were identified as outliers and excluded from the subsequent analysis. The mean exclusion rates were .05 for the study phase (min .02, max .07; mean for the Self and Close Other .04 and .05) and .04 for the test phase (min .03, max .07; mean for the Self, Close Other and New: .04, .04 and 0.5). The subjective ratings of the closeness and familiarity questionnaire to the close other are presented in Table 6.3 (1: not well at all, almost like a stranger; 10: very well, almost like myself). The ratings reported are the numbers from the eventually chosen person out of the six people listed by the participant. The ratings fit the design of the experiment that both familiarity and closeness of the person chosen are at the ceiling of the scale.

*Table 6.3. Mean rating scores of the closeness and familiarity questionnaire for a close other.*

| Question | Rating (SD) |
|---|---|
| How well do you know the person? | 9.28 (.81) |
| How well do you think the person knows you? | 9.50 (.62) |
| How close do you feel you are to the person? | 9.56 (.62) |
| How close does the person feel to you? | 9.31 (.93) |

### 6.3.1 Behavioural responses

#### 6.3.1.1 Recognition memory

Recognition memory performance was measured via Pr values, computed separated for recollection and familiarity and each level of Valence and the Reference Person (Table 6.4). A repeated-measure ANOVA with factors of Valence (Negative vs. Neutral vs. Positive), Reference Person (Self vs. Close Other), and Memory Type (Recollection vs. Familiarity) was employed for the analysis. The results indicated a main effect of Reference Person (F(1, 32) = 10.143, $\eta_p^2$ = .241, p = .003), which showed that memory was better for the Self than a Close Other (.30 vs. .26). Importantly, the interaction between Reference Person and Memory Type was also significant (F(1, 32) = 4.724, $\eta_p^2$ = .129, p = .037; Figure 6.1). Post-hoc t-tests indicated that the contribution of Recollection to the Self was higher than that for the Other (.34 vs. .28; t(32) = 5.353, p < .001) while the levels of Familiarity did not differ significantly across conditions (.26 vs. .24; t(32) = 1.272, p = .212). The interaction between Valence and Memory Type was significant (F(1.970, 63.024) = 7.020, $\eta_p^2$ = .180, p = .002). Supplementary analysis showed a significant main effect of Valence for Pr values based on recollection (F(1.939, 62.061) = 5.087, $\eta_p^2$ = .137, p = .010). Recollection of Neutral and Positive adjectives was better than recollection of Negative adjectives (Neutral vs. Negative: t(32) = 3.113, p = .004; Positive vs. Negative: t(32) = 2.183, p = .037). Recollection of Neutral and Positive adjectives did not differ (t(32) = .721, p = .476). An effect of Valence was also found for Pr values based on Familiarity (F(1.453, 46.483) = 5.382, $\eta_p^2$ = .227, p = .001). Positive adjectives elicited more Familiarity than both Negative (t(32) = 2.805, p = .008) and Neutral (t(32) = 3.609, p = .001) adjectives. The difference between Negative and Neutral adjectives on Familiarity was not significant (t(32) = 1.478, p = .149). The main effects of Valence (F(1.871, 59.870) = .450, $\eta_p^2$ = .014, p = .627), Memory Type (F(1, 32) = 2.661, $\eta_p^2$ = .077, p = .113) and the interactions between Valence and Reference Person (F(1.680, 53.763) = 2.155, $\eta_p^2$ = .133, p = .063) and between Valence, Memory Type and Reference Person (F(1.942, 62.149) = .133, $\eta_p^2$ = .004, p = .870) were not significant.

Thus, recognition memory showed a significant self-reference effect, which was limited to recollection. Irrespective of the person about which decisions had to be made, neutral and positive adjectives elicited more recollection than negative adjectives, while positive adjectives elicited more familiarity than negative and neutral adjectives.

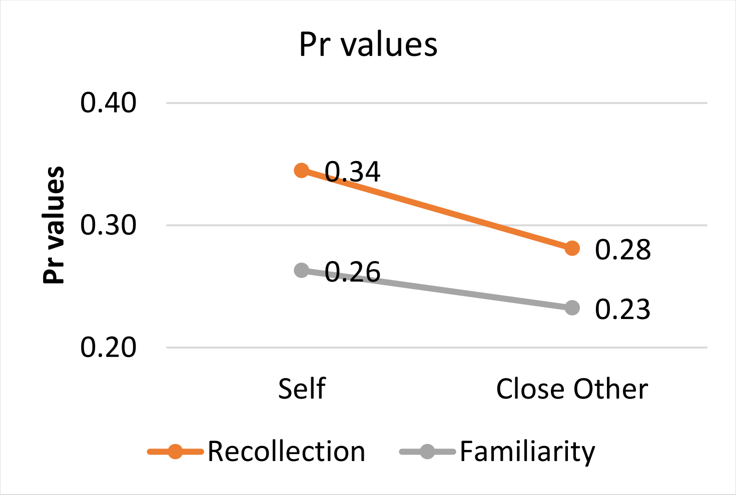

*Figure 6.1. Line graph for Pr values for the Self and a Close Other, separately for recollection and familiarity. Values are collapsed across emotional valence.*

*Table 6.4. Pr values of Recollection and Familiarity for the Self and Close Other conditions, separately for each Valence.*

| | Recollection | | | Familiarity | | |
|---|---|---|---|---|---|---|
| | Negative | Neutral | Positive | Negative | Neutral | Positive |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Self | Mean | 0.29 | 0.28 | 0.37 | 0.26 | 0.36 | 0.24 |
| | SD | 0.17 | 0.23 | 0.18 | 0.24 | 0.20 | 0.30 |
| Close Other | Mean | 0.25 | 0.29 | 0.31 | 0.22 | 0.28 | 0.20 |
| | SD | 0.18 | 0.21 | 0.18 | 0.22 | 0.18 | 0.20 |

#### 6.3.1.2 Reaction times

##### *6.3.1.2.1 Study phase*

The reaction times during the study phase (shown in Table 6.5) were analysed using a repeated-measures ANOVA with factors of Reference Person (Self vs. Close Other) and Valence (Negative vs. Neutral vs. Positive). The results showed that participants took longer to make a judgment about a Close Other than the Self (1471 ms vs. 1441 ms; F(1, 31) = 4.585, $\eta_p^2$ = .125, p = .040). The main effect of Valence was also significant (F(1.856, 59.402) = 4.012, $\eta_p^2$ = .111, p = .026). Follow-up analyses showed that participants took longer to make a judgment about Neutral relative to both Negative items (1480 ms vs. 1449 ms; t(32) = 2.401, p = .022) and Positive items (1480 ms vs. 1443 ms; t(32) = 2.802, p = .009). The difference between Negative and Positive items was not significant (t(32) = .412, p = .683). The interaction between Self and Valence (F(1.833, 58.649) = 1.443, $\eta_p^2$ = .043, p = .245) was also not significant.

*Table 6.5. Reaction times (in ms) for the Self and a Close Other during study, separately for each emotional valence.*

| | | Emotion | | |
|---|---|---|---|---|
| | | Negative | Neutral | Positive |
| Self | Mean | 1437 | 1472 | 1413 |
| | SD | 326 | 357 | 322 |
| Close Other | Mean | 1462 | 1488 | 1473 |
| | SD | 330 | 346 | 338 |

##### *6.3.1.2.2 Test phase*

A repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other) and Response Type (Remember vs. Know) was used to analyse the reaction times during the test phase. The results indicated that the main effects of Reference Person (F(1, 32) = 4.923, $\eta_p^2$ = .133, p = .034) and Response Type (F(1, 32) = 15.296, $\eta_p^2$ = .323, p < .001) were significant, with participants taking longer to make a judgment about a Close Other than the Self (1402 ms vs. 1371 ms), and for Know than Remember responses (1502 ms vs. 1271 ms). The interaction between Reference Person and Response Type was not significant (F(1, 32) = .991, $\eta_p^2$ = .030, p = .327).

#### 6.3.1.3 Summary

In this experiment, a significant SRE was found, indicating that items encoded in relation to the self were remembered better than items encoded in relation to a close other. In addition, the SRE was limited to recollection and did not occur for familiarity-based responses. Interestingly, neutral and positive items showed higher proportions of recollection than negative items. In contrast, negative items showed a higher proportion of familiarity than neutral and positive items. During encoding, participants took longer to make a judgment about a neutral item than to negative and positive items. Participants also showed a significant pattern of taking longer to make a judgment in relation to a close other than to the self during both encoding and retrieval.

### 6.3.2 Event-related potentials

A total of 18 electrodes on the scalp were selected and partitioned into left-frontal, right-frontal, left-central, right-central, left-parietal and right-parietal regions (Figure 6.2). The purpose of this electrode selection was to achieve an optimal coverage of the scalp yet retain statistical power and reveal effects that vary across hemisphere, caudality, or both. Regional mean potentials were calculated based on the partitions and experimental conditions and were submitted into the ANOVAs with the levels of hemispheres and caudality.

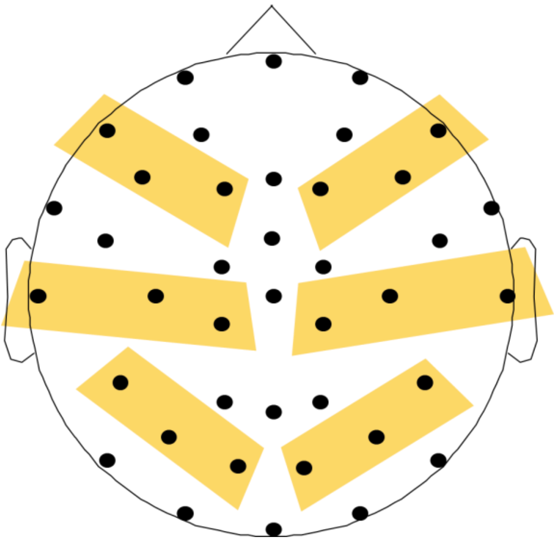

*Figure 6.2. Electrodes selected for the analysis of ERPs, chosen from left-frontal (left to right: 49, 33, 19), right-frontal (left to right: 9, 22, 37), left-central (left to right: 47, 17, 6),*

*right-central (left to right: 4, 11, 39), left-parietal (left to right: 30, 29, 28) and right-frontal (left to right: 27, 26, 25) regions (M10 https://www.easycap.de/wordpress/wp-content/uploads/2018/02/Easycap-Equidistant-Layouts.pdf).*

### 6.3.2.1 Study phase

#### *6.3.2.1.1 Pre-stimulus*

The ERPs elicited by cues preceding words that were subsequently Remembered and Forgotten items showed small changes across the scalp and time for both Self and Close Other (Figure 6.3). The differences between Remembered and Forgotten for Self seem more focused on central sites, whereas the differences between Remembered and Forgotten for Close Other seem focused on right frontal site.

In order to reveal the time course of any pre-stimulus brain activity related to successful encoding, the brain activity in the interval between the cue and adjective was analysed with consecutive time windows of 250 ms (Otten et al., 2006). The mean amplitudes during these time windows were submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other), Memory (Remembered vs. Forgotten), Time Window (0-250 ms vs. 250-500 ms vs. 500-750 ms vs. 750-1000 ms vs. 1000-1250 ms vs. 1250-1500 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). Remembered condition consists of items subsequently received Remember response, while Forgotten condition consists of items subsequently received either Know or New responses to gain sufficient numbers of trials. The results showed a significant interaction between Memory and Hemisphere (F(1, 23) = 4.363, $\eta_p^2$ = .159, p = .048). No other significant effects related to Memory were found[12]. Supplementary analyses on values from electrodes on the left[13] and right[14] sides of the scalp did not

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[12] The main effect of Memory (F(1, 23) = .643, $\eta_p^2$ = .027, p = .429), interactions between Time Window and Memory (F(2.4, 54.50) = 1.172, $\eta_p^2$ = .049, p = .324), between Reference Person and Memory (F(1, 23) = .003, $\eta_p^2$ < .001, p = .956), between Caudality and Memory (F(1.7, 39.3) = .666, $\eta_p^2$ = .028, p = .495), between Time Window, Reference Person and Memory (F(2.3, 53.3) = .068, $\eta_p^2$ = .003, p = .953), between Time Window, Caudality and Memory (F(3.5, 79.4) = .385, $\eta_p^2$ = .017, p = .790), between Time Window, Hemisphere and Memory (F(2.4, 56.3) = 1.406, $\eta_p^2$ = .057, p = .254), between Reference Person, Caudality and Memory (F(1.5, 34.7) = .713, $\eta_p^2$ = .030, p = .458), between Reference Person, Hemisphere and Memory (F(1, 23) = .002, $\eta_p^2$ < .001, p = .969), between Caudality, Hemisphere and Memory (F(2.0, 45.7) = 2.778, $\eta_p^2$ = .108, p = .073), between Time Window, Reference Person, Caudality and Memory (F(3.2, 74.2) = 1.172, $\eta_p^2$ = .048, p = .329), between Time Window, Reference Person, Hemisphere and Memory (F(3.0, 67.9) = .212, $\eta_p^2$ = .009, p = .885), between Reference Person, Caudality, Hemisphere and Memory (F(1.9, 43.1) = .936, $\eta_p^2$ = .040, p = .392), between Time Window, Reference Person, Caudality, Hemisphere and Memory (F(3.1, 72.3) = .347, $\eta_p^2$ = .015, p = .799) were not significant.

[13] The main effect of Memory (F(1, 23) = .071, $\eta_p^2$ = .003, p = .791), the interactions between Time Window and Memory (F(2.6, 59.2) = .664, $\eta_p^2$ = .028, p = .554), between Reference Person and Memory (F(1, 23) = .002, $\eta_p^2$ < .001, p = .964), between Caudality and Memory (F(1.7, 39.1) = .014, $\eta_p^2$ = .001, p = .975), between Time Window, Reference Person and Memory (F(2.4, 55.9) = .108, $\eta_p^2$ = .005, p = .929), between Time Window, Caudality and Memory (F(3.6, 82.0) = .588, $\eta_p^2$ = .025, p = .652), between Reference Person, Caudality and Memory (F(1.6, 37.7) = .652, $\eta_p^2$ = .027, p = .495) and between Time Window, Reference Person, Caudality and Memory (F(3.4, 78.8) = 1.016, $\eta_p^2$ = .042, p = .398) were not significant.

[14] The main effect of Memory (F(1, 23) = 1.663, $\eta_p^2$ = .067, p = .211), the interactions between Time Window and Memory (F(2.3, 52.5) = 1.653, $\eta_p^2$ = .068, p = .199), between Reference Person and Memory (F(1, 23) = .003, $\eta_p^2$ < .001, p = .955), between Caudality and Memory (F(1.9, 43.4) = 2.282, $\eta_p^2$ = .091, p = .117), between Time Window, Reference Person and Memory (F(2.3, 52.9) = .047, $\eta_p^2$ = .002, p = .968), between Time Window, Caudality and Memory (F(3.5, 79.4) = .419, $\eta_p^2$ = .018, p = .766), between Reference Person, Caudality and Memory (F(1.8, 41.7) = .896, $\eta_p^2$ = .037, p = .405) and between Time Window, Reference Person, Caudality and Memory (F(3.2, 73.7) = 1.079, $\eta_p^2$ = .045, p = .367) were not significant.

reveal significant effects relevant to Memory. Thus, the data did not show significant pre-stimulus subsequent memory effects.

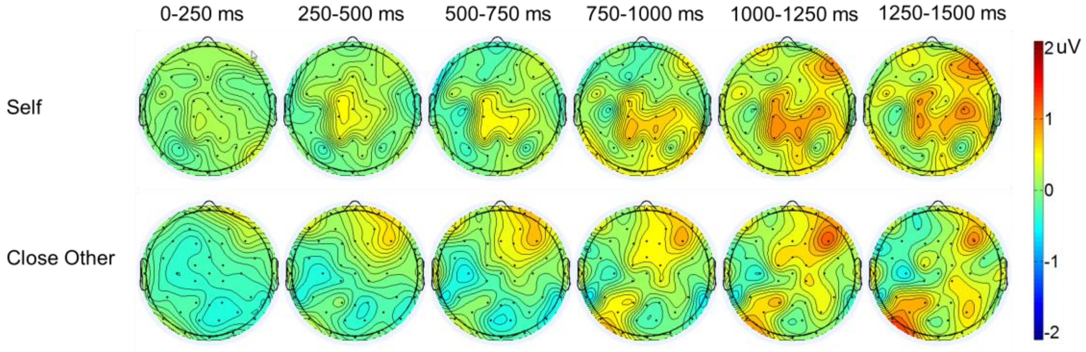

*Figure 6.3. Spline maps showing the difference between the ERPs for adjectives that were later remembered and forgotten for the Self (top) and a Distant Other (bottom). Differences are shown for the six analysed time windows (0-250, 250-500, 500-750, 750-1000, 1000-1250 and 1250-1500 ms) in the interval between the cue and adjective.*

#### *6.3.2.1.2 Post-stimulus*

The ERPs elicited by words that were subsequently Remembered and Forgotten items showed frontally-distributed differences for both Self and Close Other (Figure 6.4). For Self, the differences between Remember and Forgotten are frontally-distributed during time windows of 200-600 ms and 600-1100 ms, while the differences for Close Other are slightly right-frontally-distributed across the three time windows between 200 and 1900 ms.

The mean amplitudes in the 200-600 ms, 600-1100 ms, and 1100-1900 ms intervals after the onset of the adjectives were calculated based on previous studies suggesting the prominence of subsequent memory effects in these intervals (Galli et al., 2011). The values were submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other), Memory (Remembered vs. Forgotten), Time Window (200-600 ms vs. 600-1100 ms vs. 1100-1900 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The results showed a significant interaction between Memory, Hemisphere and Caudality (F(1.8, 42.1) = 4.212, $\eta_p^2$ = .153, p = .024). Follow-up analyses on each scalp region indicated significant interactions between Memory and Hemisphere at Frontal (F(1, 23) = 5.830, $\eta_p^2$ = .202, p = .024) and Central (F(1, 23) = 5.225, $\eta_p^2$ = .185, p = .032) regions. The interaction between Memory and Hemisphere was not significant at Parietal regions (F(1, 23) = .180, $\eta_p^2$ = .008, p = .674). Further analyses indicated a significant memory effect for the Right-Frontal region (F(1, 23) = 6.931, $\eta_p^2$ = .232, p = .015; Figure 6.5), but not Left-Frontal (F(1, 23) = .627, $\eta_p^2$

= .27, p = .435), Left-Central (F(1, 23) = .068, $\eta_p^2$ = .003, p = .796) or Right-Central (F(1, 23) = 1.519, $\eta_p^2$ = .062, p = .231) regions.

In the main analysis, there was a marginally significant interaction between Reference Person, Memory and Time Window (F(1.7, 39.2) = 3.413, $\eta_p^2$ = .129, p = .050). Subsidiary analyses showed a significant interaction between Reference Person and Memory in the 1100-1900 ms interval (F(1, 23) = 4.590, $\eta_p^2$ = .166, p = .043), but not further significant difference was found (Memory effects for Self F(1, 23) = 1.080, $\eta_p^2$ = .045, p = .311 and Close Other F(1, 23) = 2.217, $\eta_p^2$ = .088, p = .151). The interactions between Reference Person and Memory were not significant in the 200-600 ms (F(1, 23) = .033, $\eta_p^2$ = .001, p = .858) and 600-1100 ms (F(1, 23) = .510, $\eta_p^2$ = .022, p = .480) intervals. No other significant effects were found[15].

The brain activity after the onset of adjectives thus varied depending on whether the adjectives were later remembered or forgotten. This took the form of a long-lasting right-frontally distributed positive-going subsequent memory effect. This effect did not differ depending on whether an adjective was encoded in relation to the self or a close other.

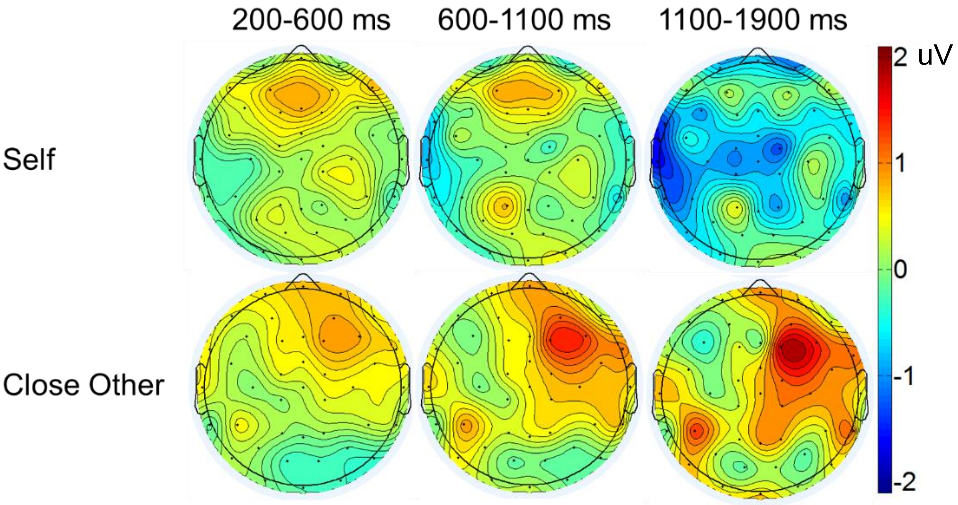

*Figure 6.4. Spline maps showing the difference between Remembered and Forgotten trials for the Self (top) and Close Other (bottom) for the three analysis windows (200-600, 600-1100, 1100-1900 ms).*

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[15] The main effect of Memory (F(1, 23) = 1.151, $\eta_p^2$ = .048, p = .295), interactions between Time Window and Memory (F(1.3, 29.3) = .775, $\eta_p^2$ = .033, p = .413), between Reference Person and Memory (F(1, 23) = 1.519, $\eta_p^2$ = .063, p = .231), between Caudality and Memory (F(1.9, 43.5) = 1.500, $\eta_p^2$ = .062, p = .236), between Hemisphere and Memory (F(1, 23) = 2.487, $\eta_p^2$ = .099, p = .129), between Time Window, Caudality and Memory (F(2.6, 60.7) = .901, $\eta_p^2$ = .038, p = .433), between Time Window, Hemisphere and Memory (F(1.4, 31.3) = 1.167, $\eta_p^2$ = .049, p = .308), between Reference Person, Caudality and Memory (F(1.5, 35.3) = .659, $\eta_p^2$ = .028, p = .483), between Reference Person, Hemisphere and Memory (F(1, 23) = .120, $\eta_p^2$ = .005, p = .731), between Time Window, Reference Person, Caudality and Memory (F(2.7, 62.7) = .283, $\eta_p^2$ = .012, p = .818), between Time Window, Reference Person, Hemisphere and Memory (F(1.9, 42.6) = .864, $\eta_p^2$ = .037, p = .419), between Time Window, Caudality, Hemisphere and Memory (F(2.5, 58.3) = 2.129, $\eta_p^2$ = .005, p = .116), between Reference Person, Caudality, Hemisphere and Memory (F(1.8, 40.7) = 2.737, $\eta_p^2$ = .108, p = .083) and between Time Window, Reference Person, Caudality, Hemisphere and Memory (F(1.7, 39.7) = 2.061, $\eta_p^2$ = .084, p = .147)

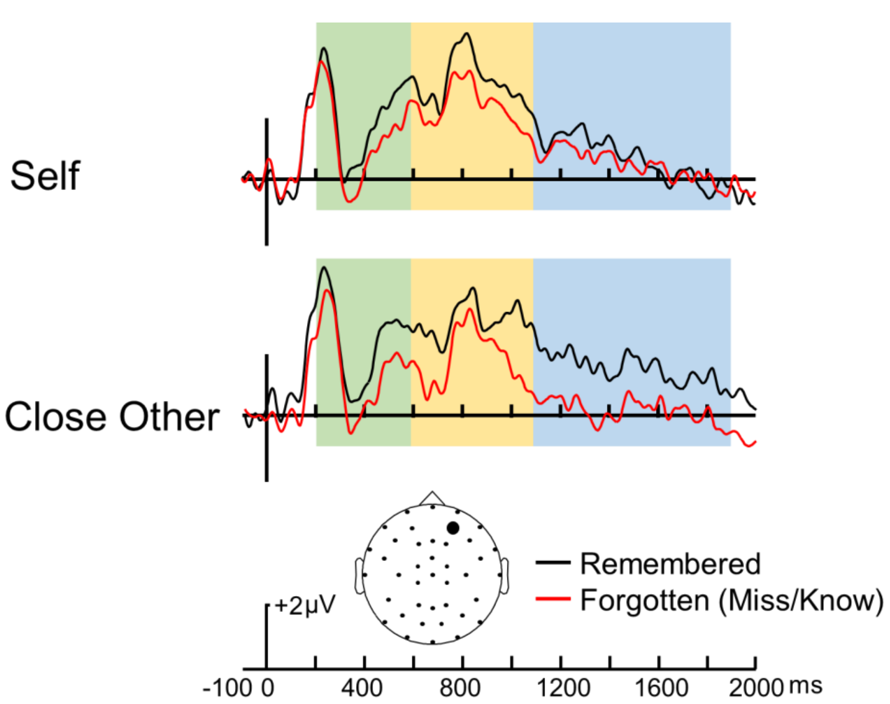

*Figure 6.5. ERP waveforms from a right-frontal electrode (21) during the study phase. The three colour shades indicate the analysis windows of 200-600 ms (green), 600-1100 (yellow) and 1100-1900 ms (blue).*

### 6.3.2.2 Test phase

Brain activities during memory retrieval were analysed with four time windows, 300-500 ms, 500-800 ms, 800-1200 ms and 1200-1600 ms. The first two windows intended to capture old/new effects associated with familiarity and recollection, namely the mid-frontal (Azimian-Faridani & Wilding, 2006; Curran, 2000; Woodruff et al., 2006) and left-parietal (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996) effects. The two late time windows intended to capture a late-onsetting, long-lasting old/new effect, the late posterior negativity (LPN; Herron, 2007; Johansson & Mecklinger, 2003). Collectively, the four time windows were able to reveal the unfolding of retrieval-related activity over time.

#### *6.3.2.2.1 Early time windows: 300-500 ms and 500-800 ms*

Retrieval-related brain activity was analysed with the same electrode selection and partitioning as encoding-related activity. The electrodes represent six regions on the scalp (left-frontal, right-frontal, left-central, right-central, left-parietal and right-parietal) to demonstrate the distribution of old/new effects across the scalp. Mean amplitudes in the two early time windows, 300-500 ms and 500-800 ms, were calculated across electrodes at the six regions on the scalp and submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other), Memory (Remember vs. Correct Rejections), Time Window (300-500 ms vs. 500-800 ms), Hemisphere (left vs. right) and Caudality (Frontal vs. Central vs. Parietal). The results showed a significant interaction between Reference Person and Memory (F(1, 23) = 5.813, $\eta_p^2$ = .202, p = .024; Figure 6.6). Follow-up analysis suggested a significant old/new effect for adjectives processed in relation to the Self (F(1, 23) = 8.557, $\eta_p^2$ = .271, p = .008) but not for adjectives processed in relation to a Close Other (F(1, 23) < .001, $\eta_p^2$ < .001, p = 1.000; Figure 6.7). No other significant interactions related to Reference Person and Memory was found[16]. The old/new effect for the Self was wide-spread and positive-going across 300-500 ms and 500-800 ms. It is worth noting that the widespread distribution in the 500-800 ms interval does not adhere to the typical left-parietal distribution of the left-parietal effect (Curran, 2004; Duzel et al., 1997).

To investigate whether the old/new effects for the self around the two time windows indeed covered mid-frontal and left-parietal regions, planned comparisons for the bilaterally-frontal scalp regions around 300-500 ms and the left-parietal scalp region around 500-800 ms were carried out. The results suggested a significant comparison for the self at the left-parietal region around 500-800 ms (F(1, 23) = 13.648, $\eta_p^2$ = .372, p = .001) but not at the left-frontal (F(1, 23) = 2.329, $\eta_p^2$ = .092, p = .141) and right-frontal (F(1, 23) = 1.645, $\eta_p^2$ = .067, p = .213) regions around 300-500 ms. The comparisons for a close other were not significant (left-frontal (F(1, 23) = .025, $\eta_p^2$ = .001, p = .876) and right-frontal (F(1, 23) = .028, $\eta_p^2$ = .001, p = .869) regions around 300-500 ms and left-parietal (F(1, 23) = .153, $\eta_p^2$ = .007, p = .698) region around 500-800 ms).

The results of the planned comparisons suggested that a significant old/new effects for the self at left parietal region around 500-800 ms. No evidence showing significant old/new effects for a close other or at bilaterally-frontal regions around 300-500 ms.

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[16] The interactions between Time Window, Reference Person and Memory (F(1, 23) = .4777, $\eta_p^2$ = .020, p = .495), between Caudality, Reference Person and Memory (F(1.5, 34.7) = 2.019, $\eta_p^2$ = .080, p = .158), between Hemisphere, Reference Person and Memory (F(1, 23) < .001, $\eta_p^2$ < .001, p = .996), between Time Window, Caudality, Reference Person and Memory (F(1.2, 26.8) = .114, $\eta_p^2$ = .005, p = .776), between Hemisphere, Reference Person and Memory (F(1, 23) = 2.429, $\eta_p^2$ = .096, p = .133), between Hemisphere, Reference Person and Memory (F(1.6, 37.5) = .251, $\eta_p^2$ = .011, p = .733) and between Time Window, Caudality, Hemisphere, Reference Person and Memory (F(1.9, 43.0) = 1.267, $\eta_p^2$ = .069, p = .292)

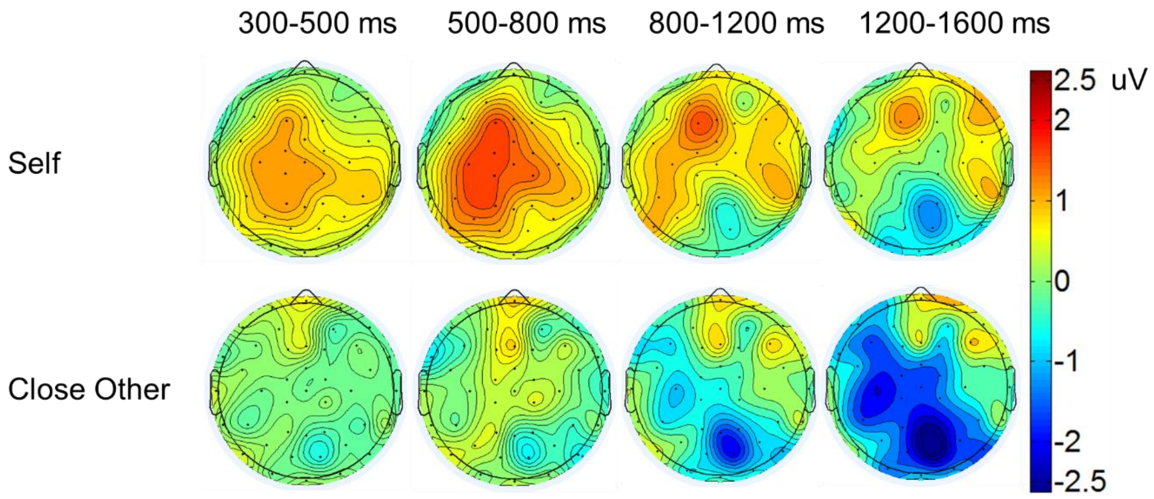


*Figure 6.6. Spline maps showing the ERP difference between remember responses and correct rejections for the self (top) and a close other (bottom) in the four analysis windows (300-500, 500-800, 800-1200, 1200-1600 ms).*

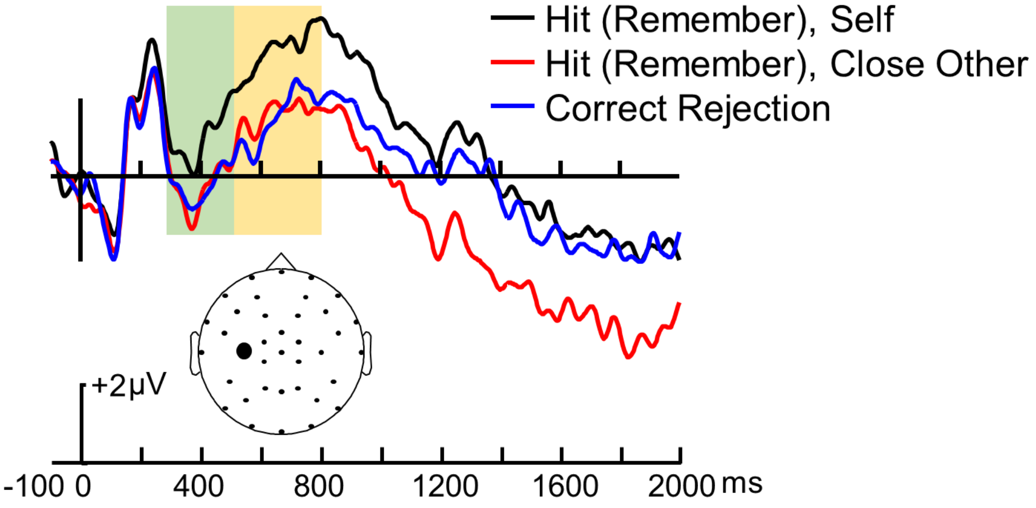
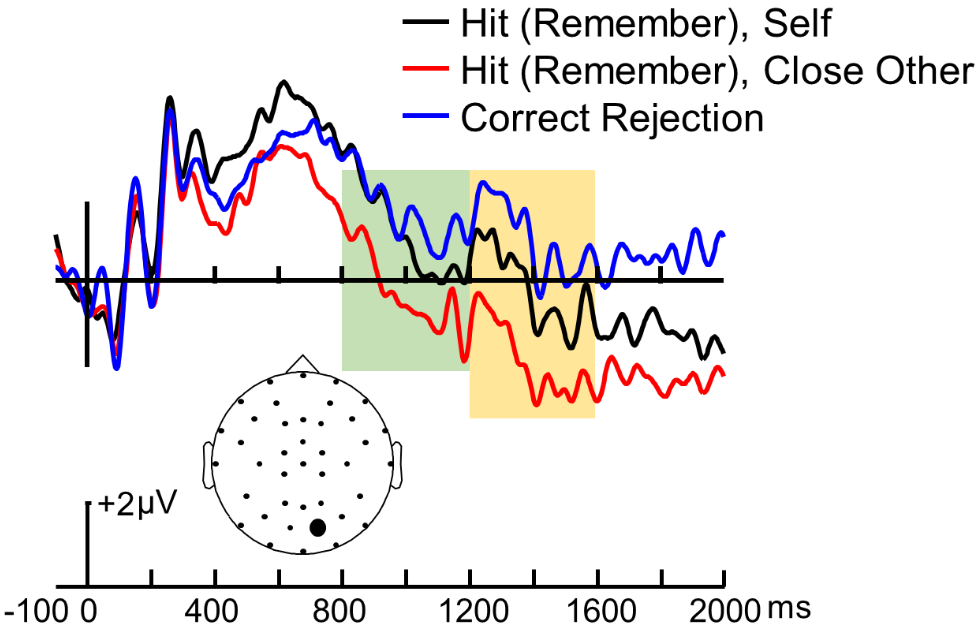


*Figure 6.7. ERP waveforms from a left-parietal electrode (17) during the test phase. The two colour shades indicate the time window of 300-500 ms (green) and 500-800 ms (yellow).*

#### *6.3.2.2.2 Late time windows: 800-1200 ms and 1200-1600 ms*

To investigate whether the sustained old/new effect visible from around 800 ms onwards varied as a function of the self versus a close other, mean amplitude values were computed in the 800-1200 ms and 1200-1600 ms intervals. The amplitudes were submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Close Other), Memory (Remember vs. Correct Rejections), Time Window (800-1200 ms vs. 1200-1600 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The ANOVA showed a significant interaction between Reference Person, Memory, Time Window, Hemisphere and Caudality (F(1.9, 43.4) = 3.703, $\eta_p^2$ = .139, p = .035). Followed-up analyses separated by the Self and Close Other indicated that, for the Self, there were no significant memory-related effects[17]. On the other hand, for Close Other, the interaction between Memory, Hemisphere and Caudality was marginally significant (F(1.4, 32.1) = 3.607, $\eta_p^2$ = .136, p = .054). The interaction between Memory, Time Window, Hemisphere and Caudality was not significant for Close Other (F(1.3, 29.7) = 1.837, $\eta_p^2$ = .074, p = .186). The mean amplitudes were therefore averaged across time windows in the subsequent analysis. For the Close Other condition, subsidiary analyses for each hemisphere indicated a significant interaction between Memory and Caudality on the Right (F(1.8, 42.0) = 3.499, $\eta_p^2$ = .130, p = .043) but not on the Left (F(1.3, 29.0) = .112, $\eta_p^2$ = .005, p = .797). For the Right Hemisphere, the old/new effect was significant at the right-parietal region (F(1, 23) = 8.734, $\eta_p^2$ = .275, p = .007; Figure 6.8) but not the right-frontal (F(1, 23) = .215, $\eta_p^2$ = .009, p = .646) or right-central (F(1, 23) = .334, $\eta_p^2$ = .014, p = .567) regions.

Thus, these analyses confirmed the observation of a long-lasting old/new effect, which was restricted to the right parietal region for items encoded in relation to a close other but not the self.



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[17] For Self, the main effect of Memory (F(1, 23) = .821, $\eta_p^2$ = .034, p = .372), interactions between Time Window and Memory (F(1, 23) = 2.240, $\eta_p^2$ = .089, p = .149), between Caudality and Memory (F(1.3, 29.8) = .638, $\eta_p^2$ = .027, p = .468), between Hemisphere and Memory (F(1, 23) = .123, $\eta_p^2$ = .005, p = .728), between Time Window, Caudality and Memory (F(1.5, 33.8) = 1.178, $\eta_p^2$ = .050, p = .308), between Time Window, Hemisphere and Memory (F(1, 23) = 3.000, $\eta_p^2$ = .115, p = .097), between Caudality, Hemisphere and Memory (F(1.5, 33.7) = .742, $\eta_p^2$ = .034, p = .443) and between Time Window, Caudality, Hemisphere and Memory (F(1.5, 35.4) = .107, $\eta_p^2$ = .005, p = .847) were not significant.

*Figure 6.8. ERP waveforms from a right-parietal electrode (27) during the test phase. The two colour shades indicate the analysis windows of 800-1200 ms (green) and 1200-1600 ms (yellow).*

#### 6.3.2.3 Summary

The ERP analyses suggest that long-lasting, positive-going activity over right-frontal scalp sites after item onset predicted later memory accuracy regardless of whether items were processed in relation to the self or a close other. Unexpectedly, no evidence for pre-stimulus subsequent memory effects was found in this experiment.

The findings during retrieval suggest temporal and spatially dissociable old/new effects to items related to the self and a close other. Retrieving items related to the self was associated with a long-lasting, widespread, positive-going old/new effect between 300 and 800 ms, when the typical time windows of the mid-frontal (Azimian-Faridani & Wilding, 2006; Curran, 2000; Woodruff et al., 2006) and left-parietal (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996) old/new effects are seen. On the other hand, retrieving items related to a close other was associated with a long-lasting, late negative-going trend of old/new effect over right parietal scalp sites during the time window of the late posterior negativity (Herron, 2007; Johansson & Mecklinger, 2003). The dissociable old/new effects for the self and a close other strongly support the idea that retrieval of information pertaining to oneself versus a close other was supported by distinct neural populations.

### 6.3.3 Oscillatory analysis

In addition to considering changes in electrical brain activity via ERPs, oscillatory analyses were carried out to address whether power changes in theta (4-7 Hz), alpha (8-12 Hz) and beta (13-30 Hz) bands are indicative of encoding-related or retrieval-related processes in relation to the self. Similar to the analysis of ERPs, the oscillatory analyses for memory encoding focused on the differences between items subsequently remembered and forgotten, the subsequent memory approach (Paller & Wagner, 2002). The analyses for memory retrieval focused on the differences between correctly recognised old and new items, the old/new effect approach (Guderian & Duzel, 2005; Hanslmayr et al., 2016; Hanslmayr & Staudigl, 2014).

#### 6.3.3.1 Study phase

The results of the analyses of encoding-related changes in oscillatory power are organised by frequency bands, capturing activity before as well as after the onset of the to-be-encoded adjectives. Pre-stimulus activity falls in the 1500 ms interval between the cue and adjective (0-1500 ms in the analysis epoch) and post-stimulus activity in the 2100 ms interval after the onset of the adjective (1500 - 3600 ms in the analysis epoch).

#### *6.3.3.1.1 Theta band activities*

The permutation tests (see Methods) showed a significant decrease in frontal theta power for adjectives that were later given a Remember as compared to New or Know response. The power decrease occurred at the end of the epoch, during 1500-2100 ms after adjective onset (3000-3600 ms after cue onset; Figure 6.9). The interaction between subsequent memory (Remember vs. New/Know) and Reference Person (Self vs. Close Other) was not significant at any electrode or time window.

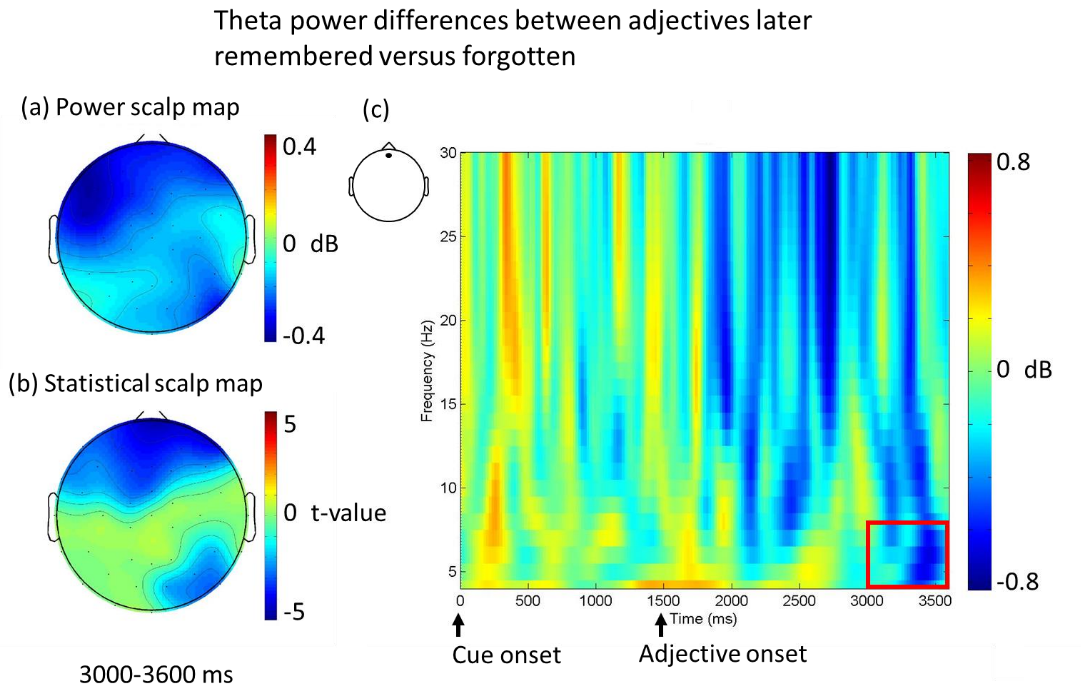


*Figure 6.9. Subsequent memory effect after stimulus onset in theta power. (a) Scalp map showing the differences in theta (4-7 Hz) power between 1500 and 2100 ms after the onset of adjectives that were later remembered versus forgotten, averaged across the Self and Close Other conditions. (b) Statistical scalp map corresponding to the power differences shown in part (a). The colour coding represents the value of the t statistics where significant differences were found ($p < 0.05$). (c) Power differences at a mid-frontal electrode site (35) showing encoding-related effects in the entire study epoch. The red square shows the statistically significant effect in the 1500-2100 ms interval after adjective onset.*

#### *6.3.3.1.2 Alpha band activities*

A frontal alpha power decrease was found to be significant for adjectives that were later given a Remember response as compared to New or Know responses in two close but separate time windows, 600-1200 ms and 1500-2100 ms after adjective onset. During 600-1200 ms, the power decrease was observed at right frontal electrodes (Figure 6.10); during the slightly later time window, 1500-2100 ms, the power decrease was found at right-frontal electrodes but more focused then the previous time window (Figure 6.11). The interaction between subsequent memory and reference person about which a decision was made was not significant at any electrode or time window.

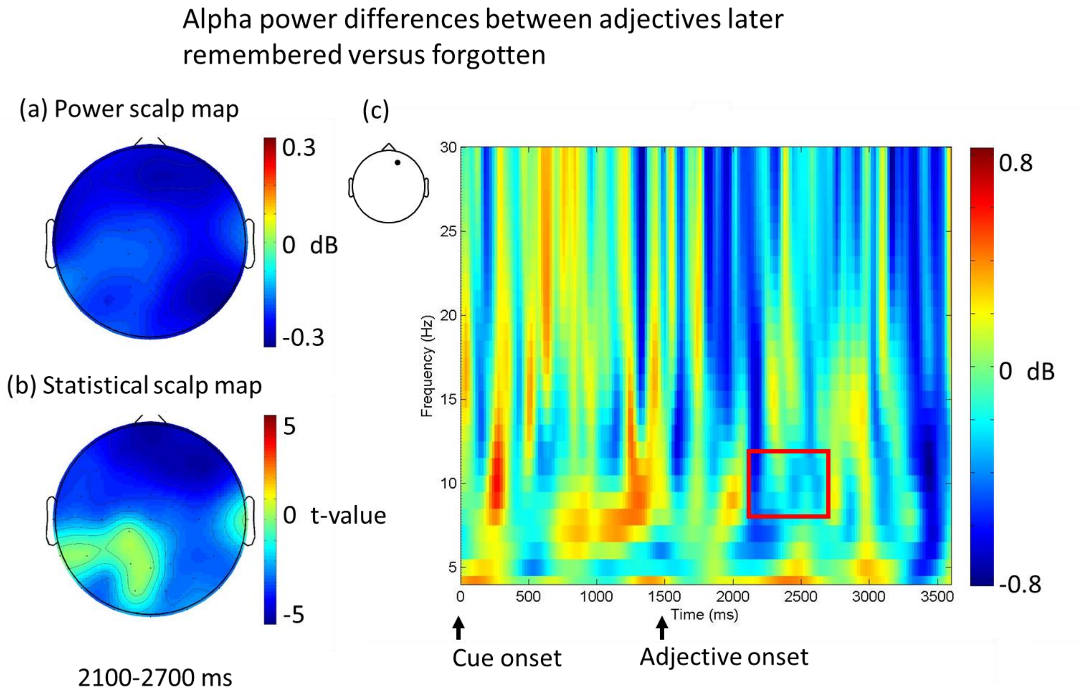


*Figure 6.10. The alpha (8-12 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Miss/Know during 600-1200 ms after adjective onset (2100-2700 ms after cue onset). Levels of Reference Person are collapsed. The colour coding in (b) represents the value of the t statistics where significant differences were found (p < 0.05). The power difference of a right-frontal electrode (21) is shown in (c), the red square shows the statistically significant frequency band and time window.*

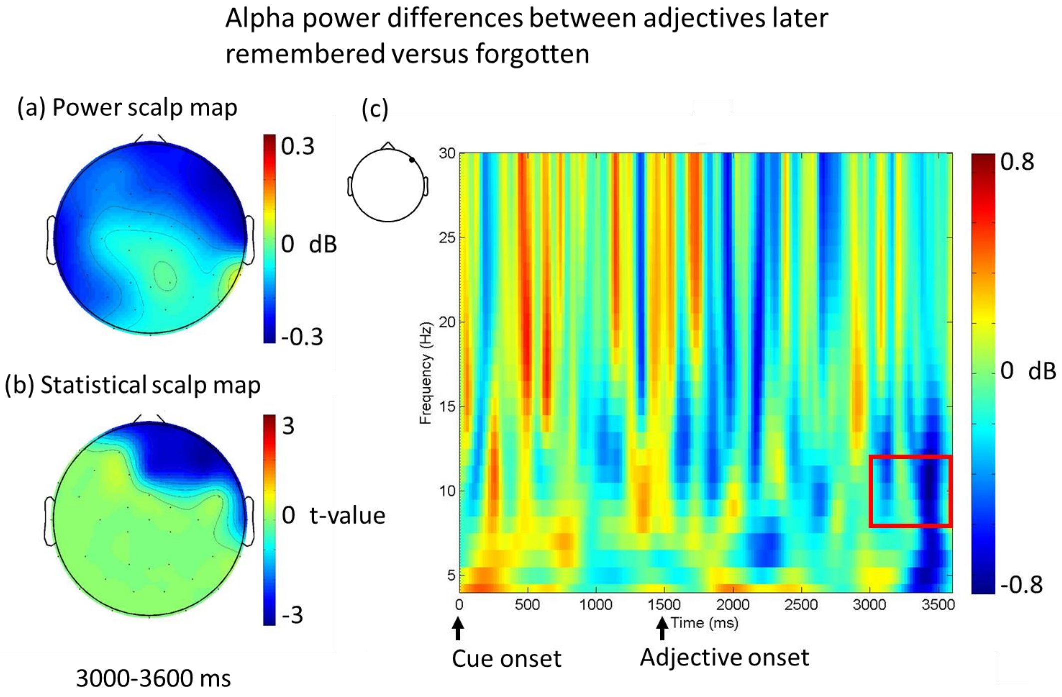


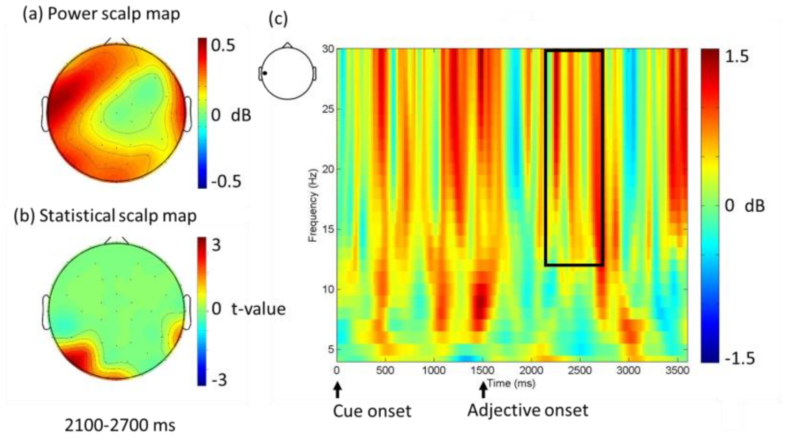
*Figure 6.11. The alpha (8-12 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Miss/Know during 1500-2100 ms after adjective onset (3000-3600 ms after cue onset). Levels of Reference Person are collapsed. The colour coding in (b) represents the value of the t statistics where significant differences were found ($p < 0.05$). The power difference of a right-frontal electrode (37) is shown in (c), the red square shows the statistically significant frequency band and time window.*

#### *6.3.3.1.3 Beta band activities*

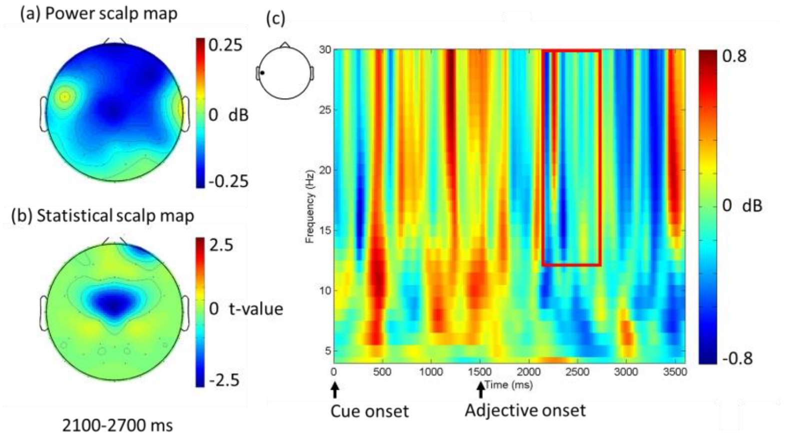
A significant interaction between subsequent memory and the reference person was found in the beta band, during 600-1200 ms after adjective onset (2100-2700 ms after cue onset). Followed-up analysis in each condition indicated that the interaction was due to a wide-spread power decrease in the Close Other but not Self condition (Figure 6.12a). For decisions about a close other, power was significantly smaller for items that were subsequently remember as opposed to forgotten across large portions of the scalp (Figure 6.12c). However, for the self, a significant power decrease was restricted to electrodes near the central part of the scalp and the decrease was also of smaller magnitude (Figure 6.12b).

Beta power differences between adjectives later remembered versus forgotten

(A) Difference in subsequent memory effects in beta power between Self and Close Other



(B) Subsequent memory effect in beta power for Self



(C) Subsequent memory effect in beta power for Close Other

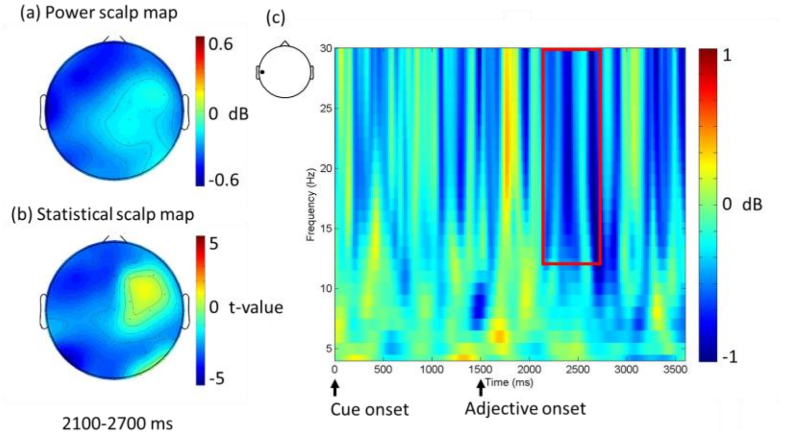


*Figure 6.12. The beta (13-30 Hz) power change (a) and statistical scalp maps (b) showing the difference of encoding-related activity between Self and Close during 600-1200 ms after adjective onset (2100-2700 ms after cue onset). The colour coding in (b) represents the value of the t statistics where significant differences were found ($p < 0.05$). The power difference of a left temporal electrode (47) is shown in (c), the black square shows the statistically significant frequency band and time window. The difference between Remember and Miss/Know for Self (B) and Close Other (C) in the same time window was shown, the red square shows the statistically significant frequency band and time window.*

#### 6.3.3.2 Test phase

##### *6.3.3.2.1 Theta band activities*

Significant old/new effects were found in the form of power decreases in the theta band over parietal scalp sites during 900-1500 ms after test item onset (Figure 6.13). The interaction between memory condition and the self was not significant in this frequency band.

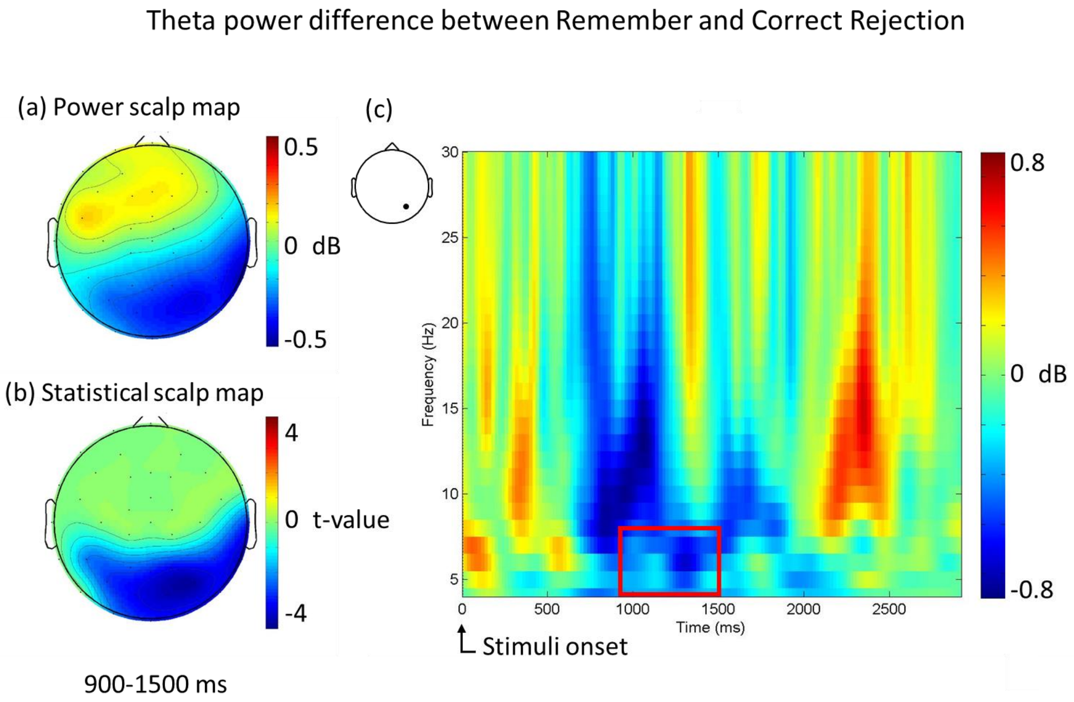


*Figure 6.13. The theta (4-7 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Correct Rejections during 900-1500 ms after test item onset. Levels of Reference Person are collapsed. The colour coding in (b) represents the value of the t statistics where significant differences were found ($p < 0.05$). The power difference of a right-posterior electrode (26) is shown in (c), the red square shows the statistically significant frequency band and time window.*

##### *6.3.3.2.2 Alpha band activities*

Significant old/new effects were also found in the alpha band, in the form of power decreases over frontal scalp sites during 600-1200 ms after test item onset (Figure 6.14). The interaction between memory condition and the self was not significant.

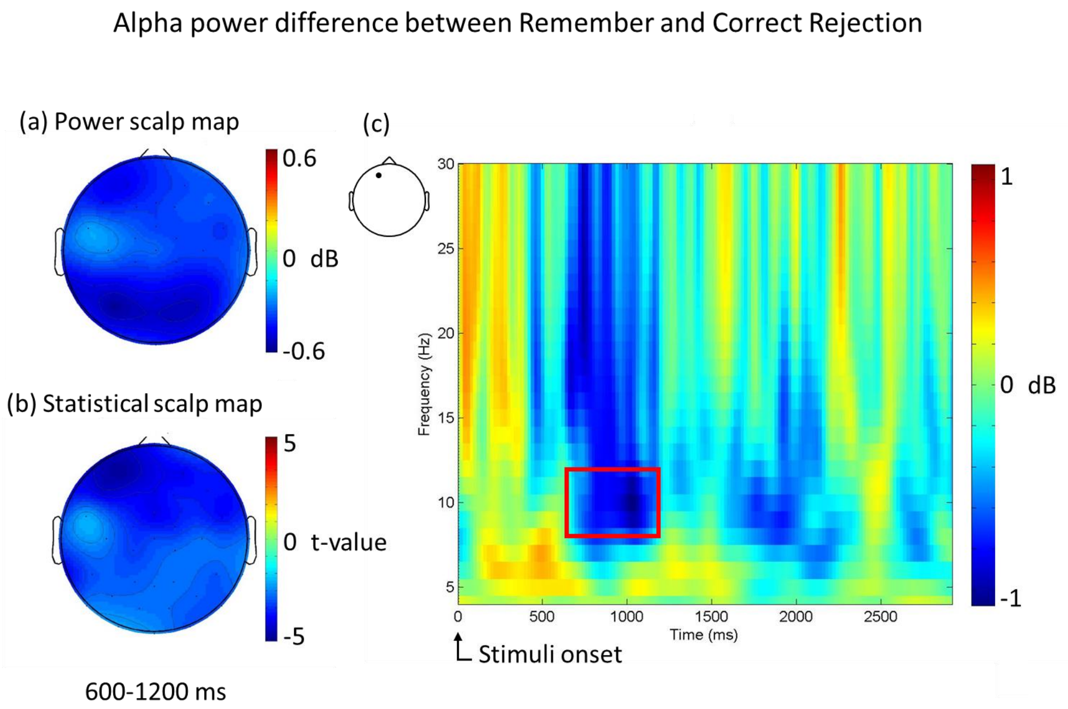


*Figure 6.14. The alpha (8-12 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Correct Rejections during 600-1200 ms after test item onset, with levels of Reference Person collapsed. The colour coding in (b) represents the value of the t statistics where significant differences were found ($p < 0.05$). The power difference of a left-frontal electrode (34) is shown in (c), the red square shows the statistically significant frequency band and time window.*

#### *6.3.3.2.3 Beta band activities*

Significant frontal-central beta power decreases were found during 600-1200 ms after the test probe when comparing items given a Remember response with correctly rejected new items (Figure 6.15). The interaction between memory condition and the self was not significant.

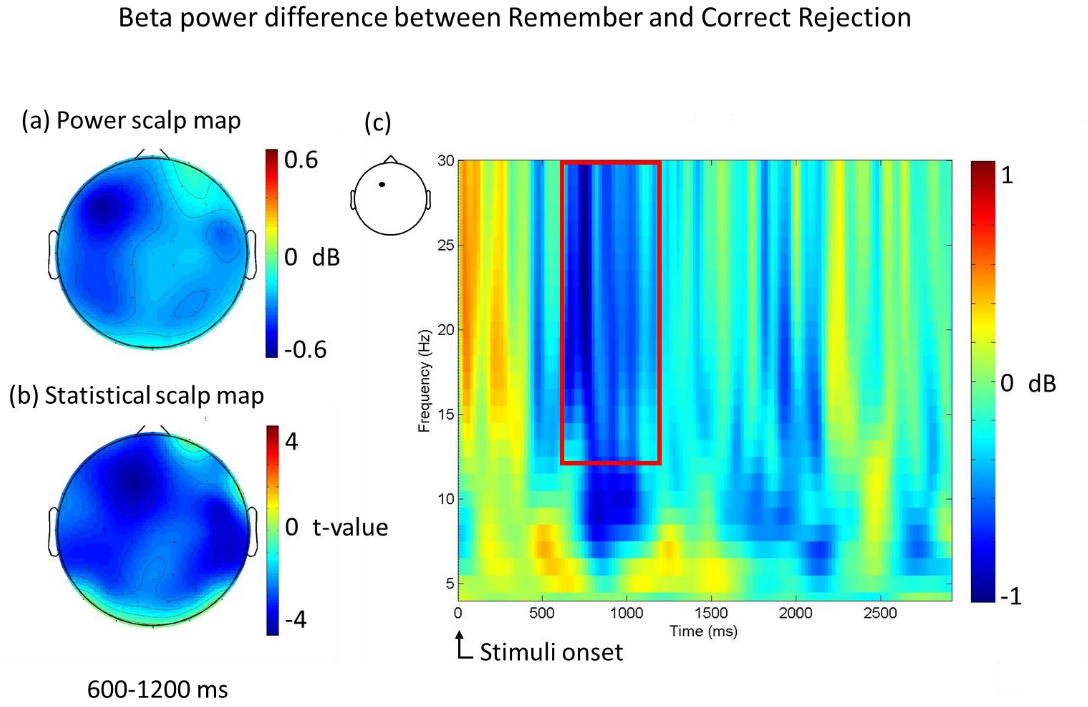


*Figure 6.15. The beta (13-30 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Correct Rejections during 600-1200 ms after test item onset, with levels of Reference Person collapsed. The colour coding in (b) represents the value of the t statistics where significant differences were found ($p < 0.05$). The power difference of a left-frontal electrode (19) is shown in (c), the red square shows the statistically significant frequency band and time window.*

#### 6.3.3.3 Summary

Encoding-related and retrieval-related differences were found in oscillatory brain activity in all three frequency bands. During encoding, a late frontal theta power decrease between 1500-2100 ms and a long-lasting, wide-spread alpha power decrease between 600-2000 ms were found after the onset of adjectives that were subsequently recollected. Importantly, a wide-spread subsequent memory effect was found in the beta band, where power decreased between 600-1200 ms following items encoded with a close other. No significant pre-stimulus oscillatory activities were found. During retrieval, parietal theta (900-1500 ms) and frontal alpha and beta power (600 -1200 ms) decreased in response to recollected old items relative to new items.

## 6.4 Discussion

Experiment 4 was designed to investigate the second research question of this thesis: ‘what are the electrophysiological activities associated with encoding and retrieving information regarding oneself?’ This question was addressed with ERPs and oscillatory activities during encoding and retrieval of items related to the self and a close other. It was hypothesised that the additional processes employed by the self to access self-schema (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997) would lead to different brain activities.

As expected, memory accuracy for information related to the self versus a close other replicated previous experiments of the thesis: the self elicited better memory than a close other, particularly on measures of recollection but not familiarity. Participants also took longer to process items related to a close other than the self during both encoding and retrieval. Importantly, ERP old/new effects during retrieval revealed significant differences depending on whether an item was processed in relation to the self or a close other. For the self, successful memory retrieval was associated with a wide-spread long-lasting positive old/new effect during 300-500 ms and 500-800 ms. On the other hand, successful memory retrieval of information pertaining to a close other was associated with a late posterior negative old/new effect during 800-1200 ms and 1200-1600 ms. The temporal and spatial dissociation of old/new effects between the self and a close other indicate that successful memory retrieval in the two conditions is supported by distinct neural populations with different time courses. In turn, this suggests that retrieval of information relating to the self and a close other involves distinct psychological mechanisms: retrieving information related to the self was associated with brain activities during the time window and scalp distribution that resembled the left-parietal effect (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996), which have been associated with recollection in episodic memory. On the other hand, retrieving information related to a close other was associated with brain activities that resembled the late posterior negativity (the 'LPN'; Herron, 2007; Johansson & Mecklinger, 2003). This effect has been related to the top-down search for to-be-retrieved information and the maintenance of retrieved information. The fact that this effect was not found for information related to the self reflects that such search and maintenance processes were larger for information related to a close other. It is interesting to note that these additional processes for a close other occur at around the time that participants gave their memory decisions via a behavioural response (mean reaction time of 1402 ms vs. ERP time windows of 800-1200 ms and 1200-1600 ms). The similar time courses of the LPN and behavioural responses may suggest that retrieving information pertaining to a close other involves psychological processes associated with the LPN. The retrieval probe did not indicate which person was correlated with the item during encoding, and the search processes captured by the LPN before giving memory decisions can therefore not be initiated by the probe itself given the predominance of the LPN in the close other condition. Rather, the search process is more likely initiated once the memory trace was retrieved in reaction to the probe and maintained for some period of time after the memory decision was given.

The dissociable old/new effects for the self and a close other in ERPs are accompanied by dissociable effects in beta oscillations during encoding. A wide-spread beta power decrease was found during encoding for a close other but not the self. It has been shown that beta power decreases during encoding might be related to semantic and conceptual processing of memory materials (Hanslmayr & Staudigl, 2014; Jensen & Mazaheri, 2010; Klimesch, 2012), and the decreases are generally more focused over left prefrontal regions for verbal materials (Hanslmayr et al., 2011) and parietal-occipital regions for pictorial materials (Noh et al., 2014). The beta power decreases found in this experiment may reflect the idea mentioned above, as the information engaged during encoding might be a mixture of both verbal and pictorial materials due to the vivid episodes retrieved by the participants in reaction to the trait adjectives. This finding suggests that when dealing with trait judgments for a close other, participants may have retrieved episodes relating to the trait adjective presented to provide sufficient details to evaluate whether the adjective is consistent with the close other. However, when dealing with trait judgments for the self, accessing self-schema (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997) might be a more efficient and effortless route to make judgments than evaluating the trait on the fly, instead of retrieving an episode of themselves and evaluating the trait again. This speculation is in line with the shorter reaction times for the self during encoding and the higher memory performance during retrieval for the self than a close other.

The dissociable beta oscillatory activities during encoding and old/new ERP effects during retrieval suggest that the self and a close other are handled differently in the context of episodic memory. This finding partially addresses one of the issues that has been raised in relation to the self, namely: is the self special? Based on the findings so far, it would be premature to completely answer the question, but the dissociable brain activities suggest that the memory traces for the self and a close other are supported by anatomically and psychologically distinct processes. This implication is also in line with previous fMRI studies suggesting that the encoding and retrieval of information pertaining to the self involve specific regions in the brain (Bergström et al., 2015; D'Argembeau, Comblain, et al., 2005; de Caso et al., 2017; Gutchess, Kensinger, Yoon, et al., 2007; Kelley et al., 2002; Leshikar & Duarte, 2014).

A long-lasting frontal subsequent memory effect was found in ERPs, regardless of whether the item was encoded in relation to the self or a close other. The time course and topography of the effect is consistent with studies suggesting that this type of subsequent memory effect reflects early attentional and perceptual processes facilitating memory encoding (Duarte et al., 2004; Otten et al., 2007) and processes focusing on the semantic meaning of the materials (Friedman & Trott, 2000; Otten & Rugg, 2001; Otten et al., 2007; Paller & Wagner, 2002). The long-lasting nature of the effect found in this experiment may also suggest that multiple psychological processes facilitate encoding at different times. There was a trend for the effect to be slightly right-lateralised for the close other, but this trend did not come out in the statistical analysis. The data thus do not show evidence that information related to the self and a close other are encoded in qualitatively different ways. Thus, even though beneficial processes of the self can be assumed to have operated given the memory advantage observed for information related to the self (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997), this does not necessarily affect the neural populations contributing to the encoding of self-relevant information. It is worth noting, however, that although qualitative differences were not observed for encoding-related processes in ERPs, they did occur for oscillatory activity.

During encoding, not only were condition-specific decreases in beta activity observed, late frontal theta and alpha power decreases were also found for items subsequently remembered versus forgotten regardless of whether items were encoded in relation to the self or a close other. The alpha power decrease is in line with previous findings suggesting that alpha power decreases are associated with successful semantic encoding (Hanslmayr et al., 2009). It is interesting to note that the alpha power decrease occurred roughly at around the time point when participants gave their trait judgements (mean reaction time of 1456 ms with a variation of about 500 ms). This may reflect such encoding process during the evaluation. The decrease in frontal theta power is compatible with earlier findings that theta power decreases are associated with successful memory encoding (Greenberg et al., 2015; Long et al., 2014), especially when forming associations between memory items (Greenberg et al., 2015). Interestingly, in the literature, the association between successful memory formation and theta power increases or decreases has been striking (e.g., Guderian et al., 2009; Hanslmayr & Staudigl, 2014; Klimesch, 1999). It has been suggested that there might be more than one anatomical mechanism contributing to the theta power change, resulting in diverse findings in the literature (Lisman & Jensen, 2013; Long et al., 2014).

During retrieval, frontal alpha and beta decreases were found for recollected items as opposed to new items, regardless of which person an item was encoded in relation to. These power decreases may reflect the inhibition of task-irrelevant brain regions and associated cognitive information during retrieval. This interpretation is in line with findings suggesting that alpha power decreases are related to functional inhibition in task-irrelevant neuronal populations (Waldhauser et al., 2012). Beta power decreases have been associated with memory suppression of irrelevant information during retrieval (Hanslmayr et al., 2012; Khader & Rosler, 2011; Nyhus, 2017; Waldhauser et al., 2015; Waldhauser et al., 2012). In addition to the alpha and beta power decreases, decreases were also found over parietal regions in the theta band for recollected items regardless of the associated person. Theta power often increases during successful memory retrieval and this has been interpreted as being the result of transient interactions between cortical regions and the hippocampus to enhance top-down control and reinstating activations for relevant episodes (Guderian & Duzel, 2005; Nyhus & Curran, 2010). However, theta power found in this experiment decreased instead of increased during recollection. It is not clear why theta showed an opposite direction of the effect. Nevertheless, the oscillation activity during retrieval suggests that retrieving information pertaining to the self and a close other relies on neuron populations related to the suppression of task-irrelevant information.

It is worth noting that the old/new effects in this experiment were based on contrasts between old items receiving remember responses and new items that were correctly rejected. Items receiving know responses did not contribute to old/new effects and these effects hence are not expected to resemble the mid-frontal effect. Nevertheless, it is still likely that items receiving remember responses received a contribution from familiarity, which may explain the presence of an old/new effect in the 300-500 ms interval. This is because it is almost impossible to have memory decisions supported by pure recollection. Alternatively, the significant old/new effect in the 300-500 ms interval may be also due to the repetition of the stimuli (the 'FN400'; Voss, Lucas, et al., 2010; Voss, Schendan, et al., 2010), instead of a contribution from familiarity. It has been shown that the mid-frontal effect might not be process-pure because it is impossible to investigate recognition memory without repetitions of the items (Paller et al., 2007; Rugg & Curran, 2007). The effect may therefore capture conceptual priming rather than familiarity. However, the uncertainty surrounding the functional interpretation of the old/new effect in the 300-500 ms interval should not detract from the fact that the effect was specific to the self and thus does not capture processes relevant to retrieving information about a close other. It is also worth noting that the old/new effect during 500-800 ms was widespread, instead of limited to left-parietal region as reported in the literature (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996). Interestingly, the widespread old/new effect related to recollection was also reported by studies using faces or objects, which elicited widespread recollection-related activity (Galli & Otten, 2011; Kuo & Van Petten, 2006). Such pattern could be related to the particular richness of the episodes (Galli & Otten, 2011). Alternatively, the usual left-parietal effect could be present as suggested by the planned comparison but may be with an additional effect in the same time window. In either case, it is interesting that the results do not always resemble the classically observed old/new effects.

Previous studies investigating pre-stimulus activities during encoding have shown ERP and power changes between items that were subsequently remembered versus forgotten. Such pre-stimulus subsequent memory effects can reflect multiple factors affecting memory formation, for example, preparation to optimise semantic encoding (Galli et al., 2012; Otten et al., 2006; Otten et al., 2010) and attention resource allocation (M. J. Gruber & Otten, 2010; Yick et al., 2016). However, in this experiment, there was no evidence that pre-stimulus activity affected subsequent memory accuracy. Participants may not have employed preparatory processes to get ready to make decisions about the self or a close other, or any such preparatory processes may not have contributed to memory accuracy. This issue can be addressed by experiments varying the instructions to the participants whether to strictly use the cue to prepare information about the person. If indeed the pre-stimulus subsequent memory effect requires specific top-down control in the context of the SRE, then such pre-stimulus subsequent memory effect may be observed in the conditions instructing participants to strictly prepare for the upcoming stimuli.

To summarise, this experiment was designed to address the electrophysiological activities associated with encoding and retrieving information regarding oneself and a close other. The behavioural results replicated the superior recollection for the self than a close other, as found in previous experiments in the thesis. Importantly, oscillatory activities during encoding showed different patterns depending on whether information was encoded in relation to the self or a close other. Brain activities during retrieval also revealed temporally and spatially dissociable old/new effects for the successful retrieval of information related to the self and a close other. These observations confirm that even when comparing the self with a highly familiar and close other, the self is still handled differently in episodic memory. In the next chapter, the electrophysiological activities of the self are compared with a familiar but distant other.

# Chapter 7. Experiment 5: the self-reference effect with the self and a distant other using ERP and oscillatory analysis

## 7.1 Introduction

As Experiment 4 described in the previous chapter, Experiment 5 was designed to address the neural correlates of encoding and retrieving information about oneself. In contrast to comparing the self with a close other, the self was compared with a distant other in Experiment 5. In the previous behavioural experiments in this thesis, information pertaining to the self was always remembered better than information pertaining to a distant other. This effect was especially seen for items that were recollected. Including a distant other in the current EEG experiment served to provide an additional, important comparison point for the self. The distant other was assumed to have the equivalent level of familiarity as the self and a close other but differed in level of closeness. This allows the further investigation of the role of closeness to others on memory-related electrophysiological activities. If closeness to others affects the neural correlates of person-related processing, distinct activities are expected in relation to processing the self and a distant other. In combination with the findings from the previous experiment, the current experiment should be able to reveal whether closeness to others contributes to the SRE and whether there is anything specific about processing the self. To date, there have to my knowledge not been any studies that have addressed the electrophysiological activities for the self and a distant other. It is possible that the additional elaborative and organisational processes employed by the self (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997) give rise to qualitatively different brain activities during encoding and retrieval. These predictions are addressed below in the experiment.

## 7.2 Methods

### 7.2.1 Participants

Thirty right-handed, native English speakers volunteered to participate in the experiment (mean age 27 years, range 19-41 years; 17 male). All participants had normal or corrected-to-normal vision and reported no history of neurological or psychological illness. Written consent forms were acquired before individuals participated in the experiment. They were paid £7.50 per hour for their participation. The experimental procedures were approved by the University College London Research Ethics Committee.

### 7.2.2 Stimulus materials

The materials used in this experiment were identical to those used in Experiment 2. The words were presented in written form in black against a 50% grey background (visual angle of about 2.5 degrees horizontally and 1 degree vertically). An additional 12 adjectives were used in the practices.

### 7.2.3 Procedure

The experimental procedures were similar to those in Experiments 1 and 2, except that the encoding conditions consisted of the Self and a Distant Other. The distant other was randomly chosen from a list of four: James Bond, Harry Potter, Sherlock Holmes and Homer Simpson. These are fictional characters that in the UK most undergraduate students are familiar with. Each participant was asked to rate how familiar they were with the chosen character using a 10-point scale, with 1 meaning knowing nothing about the character (just like a stranger) and 10 knowing almost everything about the character (just like themselves). If the rating given by the participant was lower than 7, another character from the list was assigned until it was rated higher than 7.

The study phase was separated into two blocks and the test phase into three blocks. Brief breaks were provided in between blocks. All conditions were intermixed randomly in both phases.

### 7.2.4 EEG acquisition, ERP analysis and oscillation analysis

The details of the EEG methodology were identical to those in Experiment 1. Six out of the 30 participants were excluded from the statistical analysis of the ERP and oscillatory data due to insufficient trial numbers in the conditions of interests (same criteria as Experiment 4: fewer than 15 trials for ERPs and 14 trials for oscillations. Mean, standard deviation (SD), maximum and minimum trials numbers for each condition for ERP and time-frequency analysis are listed in Table 7.1 and Table 7.2 below). Trials included in the ERP and time-frequency analysis were 93% and 87% overlapped for encoding and retrieval data.

*Table 7.1. Trial numbers for each condition of the ERP analysis, Experiment 5.*

| Condition | | | Mean | SD | Max | Min |
|---|---|---|---|---|---|---|
| Pre-stimulus | Remember | Self | 51 | 20 | 89 | 19 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Close Other | 39 | 16 | 84 | 18 |
| | Forgotten (Miss + Know) | Self | 46 | 16 | 78 | 17 |
| | | Close Other | 57 | 16 | 86 | 23 |
| Post-Stimulus | Remember | Self | 51 | 20 | 89 | 19 |
| | | Close Other | 39 | 17 | 85 | 18 |
| | Forgotten (Miss + Know) | Self | 45 | 15 | 77 | 17 |
| | | Close Other | 56 | 17 | 86 | 23 |
| Retrieval | Remember | Self | 50 | 18 | 90 | 21 |
| | | Close Other | 37 | 15 | 84 | 15 |
| | Correct Rejection | | 58 | 20 | 94 | 17 |

*Table 7.2. Trial numbers for each condition of the time-frequency analysis, Experiment 5.*

| Condition | | | Mean | SD | Max | Min |
|---|---|---|---|---|---|---|
| Encoding | Remember | Self | 50 | 17 | 83 | 23 |
| | | Close Other | 39 | 15 | 76 | 18 |
| | Forgotten (Miss + Know) | Self | 46 | 16 | 76 | 15 |
| | | Close Other | 56 | 16 | 81 | 17 |
| Retrieval | Remember | Self | 59 | 20 | 96 | 25 |
| | | Close Other | 43 | 16 | 80 | 22 |
| | Correct Rejection | | 67 | 17 | 87 | 18 |

## 7.3 Results

Trials with reaction times more or less than two standard deviations from the mean were identified as outliers and excluded from the subsequent analysis. The mean exclusion rates were .05 for the study phase (min .02, max .08; mean for the Self and Close Other .05 and .06) and .05 for the test phase (min .03, max .08; mean for the Self, Close Other and New: .04, .05 and 0.5).

### 7.3.1 Behavioural responses

#### 7.3.1.1 Recognition memory

Recognition memory performance was indexed via Pr values for recollection and familiarity, computed separately for each valence and person about whom a decision had to be made (Table 7.3 and Table 7.3). A repeated-measures ANOVA with factors of

Valence (Negative vs. Neutral vs. Positive), Reference Person (Self vs. Distant Other), and Memory Type (Recollection vs. Familiarity) was employed for the analysis. The results showed a main effect of Reference Person (F(1, 29) = 41.235, $\eta_p^2$ = .587, p < .001), indicating that memory was better for the Self than a Distant Other (respectively .33 vs. .24). Importantly, the interaction between Reference Person and Memory Type was also significant (F(1, 29) = 11.178, $\eta_p^2$ = .278, p = .002). Subsidiary analyses for recollection and familiarity indicated that both were higher for the Self (recollection: t(29) = 8.456, p < .001; familiarity: t(29) = 3.050, p = .005). The difference for recollection (.35 vs. .23) was larger than that for familiarity (.31 vs. .25), however. The main effects of Valence (F(1.922, 55.737) = 1.787, $\eta_p^2$ = .058, p = .178) and Memory Type (F(1, 29) = .111, $\eta_p^2$ = .004, p = .742) and the interactions between Valence and Memory Type (F(1.906, 55.280) = .426, $\eta_p^2$ = .014, p = .645), between Valence and Reference Person (F(1.943, 56.350) = .374, $\eta_p^2$ = .013, p = .684) and between Valence, Memory Type and Reference Person (F(1.774, 51.453) = 1.179, $\eta_p^2$ = .039, p = .311) were not significant.

Thus, memory accuracy showed a significant self-reference effect in that participants remembered items pertaining to the self better than items pertaining to a distant other. This difference was larger for responses based on recollection than familiarity.

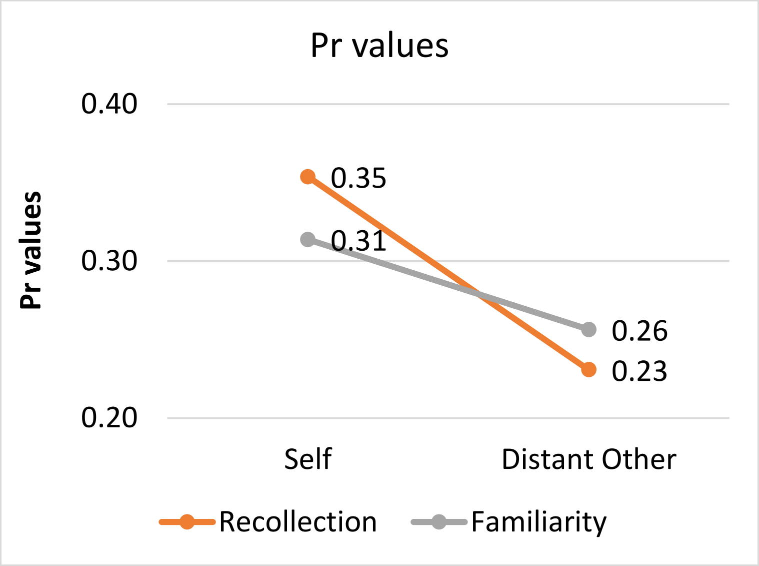


*Figure 7.1. Pr values for the self and a distant other, separately for recollection and familiarity. Values are collapsed across emotional valences.*

*Table 7.3. Pr values for recollection and familiarity for the self and a close other, separately for each emotional valence.*

| | | Recollection | | | Familiarity | | |
|---|---|---|---|---|---|---|---|
| | | Negative | Neutral | Positive | Negative | Neutral | Positive |
| Self | Mean | 0.33 | 0.32 | 0.37 | 0.32 | 0.36 | 0.30 |
| | SD | 0.21 | 0.20 | 0.22 | 0.23 | 0.21 | 0.22 |
| Close Other | Mean | 0.22 | 0.24 | 0.26 | 0.26 | 0.21 | 0.25 |
| | SD | 0.17 | 0.19 | 0.19 | 0.22 | 0.15 | 0.16 |

#### 7.3.1.2 Reaction times

##### *7.3.1.2.1 Study phase*

The reaction times for consistency judgments (shown in Table 7.4) were analysed with a repeated-measures ANOVA with factors of Reference Person (Self vs. Distant Other) and Valence (Negative vs. Neutral vs. Positive). The results showed that participants took longer to make a judgment about a Distant Other than the Self (respectively 1444 ms vs. 1377 ms), as indicated by a main effect of Reference Person (F(1, 29) = 28.301, $\eta_p^2$ = .494, p < .001). The main effect of Valence was also significant (F(1.860, 53.929) = 3.675, $\eta_p^2$ = .112, p = .035). Follow-up analyses suggested that participants took longer to make a judgment about neutral than positive items (1423 ms vs. 1391 ms; t(29) = 2.465, p = .020). The differences between neutral and negative items (p = .510) and negative and positive items (p = .074) were not significant. These main effects were modulated by a significant interaction between Reference Person and Valence F(1.993, 57.795) = 4.311, $\eta_p^2$ = .129, p = .018). Follow-up analyses suggested that participants took longer to make a judgment about a distant other than to the self for negative (1451 ms vs. 1381 ms; t(29) = 3.682, p = .001) and positive (1442 ms vs. 1341 ms; t(29) = 4.755, p < .001) items, but not for neutral items (t(29) = 1.711, p = .098).

*Table 7.4. Reaction times (in ms) for the self and a distant other during the study phase, separately for each emotional valence.*

| | | Emotion | | |
|---|---|---|---|---|
| | | Negative | Neutral | Positive |
| Self | Mean | 1381 | 1409 | 1341 |
| | SD | 302 | 295 | 268 |
| Distant Other | Mean | 1451 | 1437 | 1442 |
| | SD | 325 | 317 | 330 |

#### *7.3.1.2.2 Test phase*

A repeated-measures ANOVA employing factors of Reference Person (Self vs. Distant Other) and Memory Type (Remember vs. Know) was used to analyse the reaction times during the test phase. The results indicated significant main effects of Memory Type (F(1, 32) = 28.396, $\eta_p^2$ = .495, p < .001) and Reference Person about whom a decision had to be made (F(1, 32) = 9.927, $\eta_p^2$ = .255, p = .04). Participants took longer to make Know judgments than Remember judgments (1384 ms vs. 1223 ms), and to make decisions about a Distant Other than the Self (1326 ms vs. 1281 ms). The interaction between Reference Person and Memory Type was not significant (F(1, 29) = .011, $\eta_p^2$ < .001, p = .919).

### 7.3.1.3 Summary

A significant SRE was found in this experiment. Information processed in relation to the self was remembered better than information processed in relation to a distant other. Importantly, the memory advantage was particularly pronounced for responses based on recollection. This finding replicates the findings from previous experiments in this thesis. Memory accuracy did not differ according to emotional valence. Interestingly, however, when dealing with negative and positive items, participants took longer to make a consistency judgment at study when the items were processed in relation to a distant other rather than the self. This trend was not significant for neutral items. Participants took longer to make a judgment about a distant other than to the self during retrieval.

## 7.3.2 Event-related potentials

The electrodes selected for statistical analysis were the same as those in Experiment 4 (Figure 6.2). The electrodes were partitioned in the same manner to achieve optimal coverage of the scalp yet retain statistical power to reveal effects that varied across hemisphere, caudality or both. Regional mean potentials were calculated based on the partitions and experimental conditions.

### 7.3.2.1 Study phase

#### *7.3.2.1.1 Pre-stimulus*

Brain activity during the pre-stimulus interval was analysed with consecutive time windows of 250 ms, starting at the onset of the cue until the target adjective. This was done to investigate the time course of preparatory activity supporting later encoding (Otten et al., 2006). The mean amplitudes during these time windows were submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Distant

Other), Memory (Remembered vs. Forgotten in the later recognition test), Time Window (0-250 ms vs. 250-500 ms vs. 500-750 ms vs. 750-1000 ms vs. 1000-1250 ms vs. 1250-1500 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The ANOVA showed a marginally significant interaction between Memory and Time Window (F(3.0, 70.1) = 2.636, $\eta_p^2$ = .436, p = .056; Figure 7.2). Subsidiary analysis by each levels of Time Window suggest that during 0-250 ms, there was a significant interaction between Reference Person, Hemisphere and Memory (F(1, 23) = 5.205, $\eta_p^2$ = .185, p = .023)[18]. Further analysis separated by Reference Person did not reveal any significant effects relevant to Memory for either Self[19] or Distant Other[20] conditions. Further analyses for time windows of 250-500 ms[21], 500-750 ms[22], 750-1000 ms[23], 1000-

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[18] For 0-250 ms, the main effect of Memory (F(1, 23) = .001, $\eta_p^2$ < .001, p = .974), interactions between Reference Person and Memory (F(1, 23) = .237, $\eta_p^2$ = .010, p = .629), between Caudality and Memory (F(1.2, 28.4) = 3.371, $\eta_p^2$ = .125, p = .069), between Hemisphere and Memory (F(1, 23) = .381, $\eta_p^2$ = .016, p = .541), between Reference Person, Caudality and Memory (F(1.2, 27.1) = .547, $\eta_p^2$ = .024, p = .492), between Caudality, Hemisphere and Memory (F(1.4, 32.8) = .140, $\eta_p^2$ = .007, p = .797), between Reference Person, Caudality, Hemisphere and Memory (F(1.2, 28.0) = .113, $\eta_p^2$ = .005, p = .788) were not significant.

[19] The main effect of Memory (F(1, 23) = .131, $\eta_p^2$ = .006, p = .720), interactions between Caudality and Memory (F(1.2, 28.0) = 2.194, $\eta_p^2$ = .063, p = .223), between Hemisphere and Memory (F(1, 23) = 1.760, $\eta_p^2$ = .071, p = .198) and between Caudality, Hemisphere and Memory (F(1.3, 29.8) = .267, $\eta_p^2$ = .011, p = .668) were not significant.

[20] The main effect of Memory (F(1, 23) = .136, $\eta_p^2$ = .006, p = .715), interactions between Caudality and Memory (F(1.2, 28.1) = 1.581, $\eta_p^2$ = .086, p = .147), between Hemisphere and Memory (F(1, 23) = 3.339, $\eta_p^2$ = .127, p = .081) and between Caudality, Hemisphere and Memory (F(1.3, 29.3) = .025, $\eta_p^2$ = .001, p = .920) were not significant.

[21] For 250-500 ms, the main effect of Memory (F(1, 23) = .067, $\eta_p^2$ = .003, p = .798), interactions between Reference Person and Memory (F(1, 23) = 1.563, $\eta_p^2$ = .064, p = .225), between Caudality and Memory (F(1.5, 33.6) = 3.077, $\eta_p^2$ = .121, p = .074), between Hemisphere and Memory (F(1, 23) = .146, $\eta_p^2$ = .006, p = .705), between Reference Person, Caudality and Memory (F(1.2, 27.2) = 1.201, $\eta_p^2$ = .050, p = .293), between Reference Person, Hemisphere and Memory (F(1, 23) = .981, $\eta_p^2$ = .041, p = .330), between Caudality, Hemisphere and Memory (F(1.8, 40.7) = .139, $\eta_p^2$ = .006, p = .846), between Reference Person, Caudality, Hemisphere and Memory (F(1.6, 37.1) = .740, $\eta_p^2$ = .031, p = .455) were not significant.

[22] For 500-750 ms, the main effect of Memory (F(1, 23) = .066, $\eta_p^2$ = .003, p = .799), interactions between Reference Person and Memory (F(1, 23) = .079, $\eta_p^2$ = .003, p = .781), between Caudality and Memory (F(1.4, 32.3) = .983, $\eta_p^2$ = .041, p = .356), between Hemisphere and Memory (F(1, 23) = .433, $\eta_p^2$ = .018, p = .515), between Reference Person, Caudality and Memory (F(1.3, 28.9) = 1.171, $\eta_p^2$ = .050, p = .303), between Reference Person, Hemisphere and Memory (F(1, 23) = .565, $\eta_p^2$ = .024, p = .458), between Caudality, Hemisphere and Memory (F(1.8, 41.6) = .146, $\eta_p^2$ = .006, p = .844), between Reference Person, Caudality, Hemisphere and Memory (F(1.8, 41.2) = .542, $\eta_p^2$ = .023, p = .565) were not significant.

[23] For 750-1000 ms, the main effect of Memory (F(1, 23) = 2.571, $\eta_p^2$ = .101, p = .123), interactions between Reference Person and Memory (F(1, 23) = .004, $\eta_p^2$ < .001, p = .949), between Caudality and Memory (F(1.7, 40.0) = .294, $\eta_p^2$ = .012, p = .715), between Hemisphere and Memory (F(1, 23) = .071, $\eta_p^2$ = .003, p = .791), between Reference Person, Caudality and Memory (F(1.2, 28.2) = .380, $\eta_p^2$ = .016, p = .583), between Reference Person, Hemisphere and Memory (F(1, 23) = .046, $\eta_p^2$ = .002, p = .832), between Caudality, Hemisphere and Memory (F(1.9, 44.2) = .294, $\eta_p^2$ = .013, p = .737), between Reference Person, Caudality, Hemisphere and Memory (F(2.0, 44.9) = .165, $\eta_p^2$ = .007, p = .843) were not significant.

1250 ms[24] and 1250-1500 ms[25] did not reveal any significant Memory effects. No other significant Memory effects were found in the omnibus ANOVA[26].

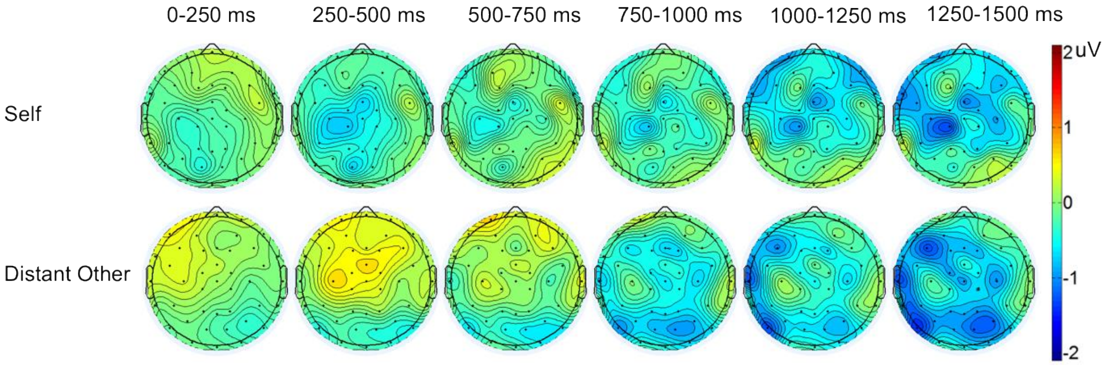

*Figure 7.2. Spline maps showing the ERP differences between items that were remembered versus forgotten in the later recognition memory test for the self (top) and a distant other (bottom) during the study phase. Values are shown for each of the six time windows that were analysed (0-250, 250-500, 500-750, 750-1000, 1000-1250 and 1250-1500 ms) during the interval between the cue and adjective.*

#### *7.3.2.1.2 Post-stimulus*

The mean amplitudes during the 200-600 ms, 600-1100 ms, and 1100-1900 ms intervals were calculated and submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Distant Other), Memory (Remembered vs. Forgotten), Time Window (200-600 ms vs. 600-1100 ms vs. 1100-1900 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The results indicated a significant interactions between Memory, Hemisphere and Caudality (F(1.8, 40.6) = 5.266, $\eta_p^2$

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[24] For 1000-1250 ms, the main effect of Memory (F(1, 23) = 2.326, $\eta_p^2$ = .092, p = .141), interactions between Reference Person and Memory (F(1, 23) = .114, $\eta_p^2$ = .005, p = .738), between Caudality and Memory (F(1.8, 40.8) = .515, $\eta_p^2$ = .022, p = .578), between Hemisphere and Memory (F(1, 23) = .405, $\eta_p^2$ = .017, p = .529), between Reference Person, Caudality and Memory (F(1.3, 29.3) = .662, $\eta_p^2$ = .029, p = .456), between Reference Person, Hemisphere and Memory (F(1, 23) = .085, $\eta_p^2$ = .004, p = .773), between Caudality, Hemisphere and Memory (F(1.9, 43.9) = .292, $\eta_p^2$ = .012, p = .737), between Reference Person, Caudality, Hemisphere and Memory (F(2.0, 45.8) = .941, $\eta_p^2$ = .039, p = .395) were not significant.

[25] For 1250-1500 ms, the main effect of Memory (F(1, 23) = 3.650, $\eta_p^2$ = .137, p = .069), interactions between Reference Person and Memory (F(1, 23) = .089, $\eta_p^2$ = .004, p = .768), between Caudality and Memory (F(1.7, 38.4) = .032, $\eta_p^2$ = .001, p = .949), between Hemisphere and Memory (F(1, 23) = 1.417, $\eta_p^2$ = .058, p = .247), between Reference Person, Caudality and Memory (F(1.2, 28.1) = .715, $\eta_p^2$ = .030, p = .430), between Reference Person, Hemisphere and Memory (F(1, 23) = .004, $\eta_p^2$ < .001, p = .949), between Caudality, Hemisphere and Memory (F(1.9, 44.0) = .297, $\eta_p^2$ = .013, p = .734), between Reference Person, Caudality, Hemisphere and Memory (F(1.9, 44.7) = 1.957, $\eta_p^2$ = .077, p = .155) were not significant.

[26] The main effect of Memory (F(1, 23) = 1.691, $\eta_p^2$ = .068, p = .207), interactions between Reference Person (F(1, 23) = .024, $\eta_p^2$ = .001, p = .878), between Caudality and Memory (F(1.6, 36.7) = .492, $\eta_p^2$ = .021, p = .572), between Hemisphere and Memory (F(1, 23) = .336, $\eta_p^2$ = .014, p = .566), between Time Window, Reference Person and Memory (F(2.3, 53.5) = .656, $\eta_p^2$ = .028, p = .543), between Time Window, Caudality and Memory (F(3.6, 82.2) = 1.896, $\eta_p^2$ = .077, p = .127), between Reference Person, Caudality and Memory (F(1.2, 28.5) = .938, $\eta_p^2$ = .038, p = .359), between Reference Person, Hemisphere and Memory (F(1, 23) = .280, $\eta_p^2$ = .012, p = .600), between Caudality, Hemisphere and Memory (F(1.9, 44.3) = .219, $\eta_p^2$ = .009, p = .795), between Time Window, Reference Person, Caudality and Memory (F(3.2, 73.9) = .299, $\eta_p^2$ = .013, p = .838), between Time Window, Reference Person, Hemisphere and Memory (F(2.8, 63.5) = 1.413, $\eta_p^2$ = .182, p = .249), between Time Window, Caudality, Hemisphere and Memory (F(3.8, 86.3) = .316, $\eta_p^2$ = .014, p = .855), between Reference Person, Caudality, Hemisphere and Memory (F(1.9, 44.4) = .828, $\eta_p^2$ = .028, p = .438) and between Time Window, Reference Person, Caudality, Hemisphere and Memory (F(3.2, 72.8) = 1.515, $\eta_p^2$ = .062, p = .217) were not significant.

= .189, p = .012) and importantly, between Reference Person, Memory, Time Window, Hemisphere and Caudality (F(2.9, 66.6) = 3.071, $\eta_p^2$ = .119, p = .035; Figure 7.3 and Figure 7.4)[27]. Further analysis separated by Reference Person suggested significant interactions between Memory, Hemisphere and Caudality (F(1.7, 39.3) = 3.593, $\eta_p^2$ = .135, p = .044) and between Memory, Time Window, Hemisphere and Caudality for Distant Other (F(2.5, 58.6) = 3.960, $\eta_p^2$ = .144, p = .017)[28] but not Self[29]. Follow-up analysis separated by Time Window suggested significant interactions between Memory, Hemisphere and Caudality during 600-1100 ms (F(1.7, 38.6) = 3.461, $\eta_p^2$ = .132, p = .040)[30] and 1100-1900 ms (F(1.8, 41.5) = 4.212, $\eta_p^2$ = .154, p = .025)[31]. The interaction during 200-600 ms was not significant[32]. However, further analysis for each Caudality during 600-1100 ms[33] and 1100-1900 ms[34] suggested no significant effects involving Memory.

Planned comparisons were carried out for left and right frontal regions on the scalp to assess the presence of the well-known positive-going subsequent memory effect over frontal scalp sites (Friedman & Trott, 2000; Otten & Rugg, 2001; Otten et al., 2007; Paller

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[27] The main effect of Memory (F(1, 23) = .506, $\eta_p^2$ = .022, p = .482), interactions between Time Window and Memory (F(1.6, 35.9) = .757, $\eta_p^2$ = .033, p = .444), between Reference Person and Memory (F(1, 23) = .981, $\eta_p^2$ = .041, p = .330), between Caudality and Memory (F(1.5, 33.5) = 1.639, $\eta_p^2$ = .068, p = .213), between Time Window, Reference Person and Memory (F(1.4, 33.1) = 1.234, $\eta_p^2$ = .050, p = .293), between Time Window, Caudality and Memory (F(2.4, 55.9) = .234, $\eta_p^2$ = .010, p = .832), between Time Window, Hemisphere and Memory (F(1.4, 32.7) = 1.138, $\eta_p^2$ = .046, p = .317), between Reference Person, Caudality and Memory (F(1.4, 31.6) = .196, $\eta_p^2$ = .009, p = .737), between Reference Person, Hemisphere and Memory (F(1, 23) = .528, $\eta_p^2$ = .022, p = .473), between Time Window, Reference Person, Caudality and Memory (F(1.9, 44.3) = 1.475, $\eta_p^2$ = .059, p = .241), between Time Window, Reference Person, Hemisphere and Memory (F(1.7, 39.8) = .427, $\eta_p^2$ = .018, p = .625), between Time Window, Caudality, Hemisphere and Memory (F(2.7, 62.9) = 2.326, $\eta_p^2$ = .090, p = .089) and between Reference Person, Caudality, Hemisphere and Memory (F(1.8, 40.5) = 1.176, $\eta_p^2$ = .050, p = .315) were not significant.

[28] The main effect of Memory (F(1, 23) = .147, $\eta_p^2$ = .006, p = .704), interactions between Time Window and Memory (F(1.5, 34.9) = .102, $\eta_p^2$ = .004, p = .850), between Caudality and Memory (F(1.7, 38.6) = .677, $\eta_p^2$ = .029, p = .487), between Hemisphere and Memory (F(1, 23) = .090, $\eta_p^2$ = .004, p = .766), between Time Window, Caudality and Memory (F(2.2, 51.4) = .963, $\eta_p^2$ = .040, p = .394) and between Time Window, Hemisphere and Memory (F(1.3, 29.1) = 1.479, $\eta_p^2$ = .062, p = .241) were not significant.

[29] The main effect of Memory (F(1, 23) = 1.596, $\eta_p^2$ = .065, p = .220), interactions between Time Window and Memory (F(1.5, 33.9) = 2.130, $\eta_p^2$ = .086, p = .146), between Caudality and Memory (F(1.4, 31.1) = 1.036, $\eta_p^2$ = .045, p = .341), between Hemisphere and Memory (F(1, 23) = .429, $\eta_p^2$ = .018, p = .517), between Time Window, Caudality and Memory (F(2.1, 48.5) = .968, $\eta_p^2$ = .040, p = .389), between Time Window, Hemisphere and Memory (F(1.9, 43.5) = .229, $\eta_p^2$ = .010, p = .784), between Caudality, Hemisphere and Memory (F(1.5, 35.3) = .758, $\eta_p^2$ = .031, p = .441) and between Time Window, Caudality, Hemisphere and Memory (F(1.9, 43.5) = .408, $\eta_p^2$ = .018, p = .730) were not significant.

[30] During 600-1100 ms, the main effect of Memory (F(1, 23) = .260, $\eta_p^2$ = .011, p = .614), interactions between Caudality and Memory (F(1.7, 38.6) = 1.367, $\eta_p^2$ = .057, p = .266) and between Hemisphere and Memory (F(1, 23) = .580, $\eta_p^2$ = .056, p = .452) were not significant.

[31] During 1100-1900 ms, the main effect of Memory (F(1, 23) = .042, $\eta_p^2$ = .002, p = .840), interactions between Caudality and Memory (F(1.7, 39.3) = .282, $\eta_p^2$ = .012, p = .720) and between Hemisphere and Memory (F(1, 23) = .047, $\eta_p^2$ = .002, p = .831) were not significant.

[32] During 200-600 ms, the main effect of Memory (F(1, 23) = .162, $\eta_p^2$ = .007, p = .690), interactions between Caudality and Memory (F(1.4, 33.0) = 1.506, $\eta_p^2$ = .060, p = .236) and between Hemisphere and Memory (F(1, 23) = .031, $\eta_p^2$ = .001, p = .862) and between Caudality, Hemisphere and Memory (F(1.5, 34.8) = 1.716, $\eta_p^2$ = .069, p = .200) were not significant.

[33] During 600-1100 ms, at Frontal, the main effect of Memory (F(1, 23) = .015, $\eta_p^2$ = .001, p = .904) and the interaction between Hemisphere and Memory (F(1, 23) = 3.388, $\eta_p^2$ = .128, p = .079), at Central, the main effect of Memory (F(1, 23) = .236, $\eta_p^2$ = .010, p = .631) and the interaction between Hemisphere and Memory (F(1, 23) = .192, $\eta_p^2$ = .008, p = .664), at Posterior, the main effect of Memory (F(1, 23) = .737, $\eta_p^2$ = .031, p = .397) and the interaction between Hemisphere and Memory (F(1, 23) = .004, $\eta_p^2$ < .001, p = .947) were not significant.

[34] During 1100-1900 ms, at Frontal, the main effect of Memory (F(1, 23) < .001, $\eta_p^2$ < .001, p = .992) and the interaction between Hemisphere and Memory (F(1, 23) = 34.791, $\eta_p^2$ = .109, p = .108), at Central, the main effect of Memory (F(1, 23) < .001, $\eta_p^2$ < .001, p = .992) and the interaction between Hemisphere and Memory (F(1, 23) = 2.802, $\eta_p^2$ = .109, p = .108), at Posterior, the main effect of Memory (F(1, 23) < .001, $\eta_p^2$ < .001, p = .992) and the interaction between Hemisphere and Memory (F(1, 23) = 2.802, $\eta_p^2$ = .109, p = .108) were not significant.

& Wagner, 2002). Significant positive-going subsequent memory effects were found for the Self at left-frontal ($F(1, 23) = 4.506$, $\eta_p^2 = .164$, $p = .045$) scalp region in the 600-1100 ms interval. No other memory-related effects were found.

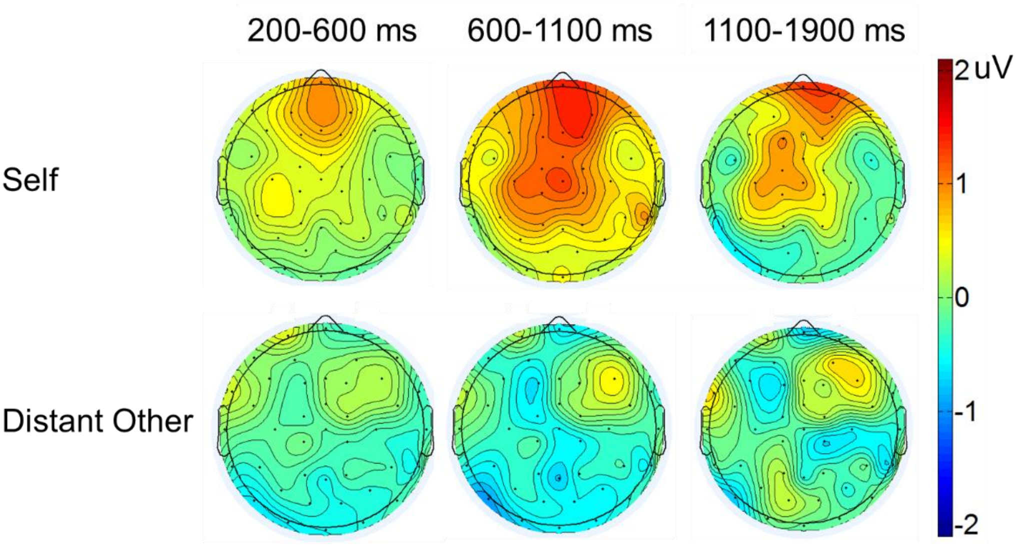

*Figure 7.3. Spline maps showing the ERP differences between items later remembered and forgotten for the self (top) and a distant other (bottom) in the three analysed time windows (200-600, 600-1100, 1100-1900 ms) after the onset of the adjectives.*

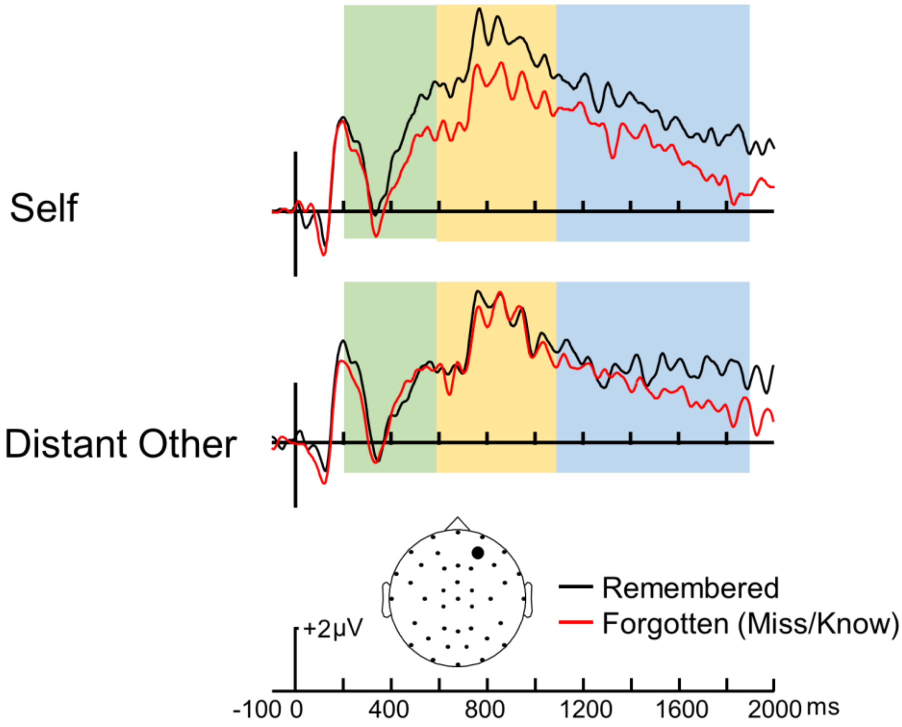

*Figure 7.4. ERP waveforms from a right-frontal electrode (21) during the study phase for adjectives that were remembered versus forgotten in the later recognition test. The three colour shades indicate the time window of 200-600 ms (green), 600-1100 (yellow) and 1100-1900 ms (blue).*

#### 7.3.2.2 Test phase

Similar to Experiment 4, the analyses of the memory retrieval data comprised time windows that covered the mid-frontal old/new effect (Azimian-Faridani & Wilding, 2006; Curran, 2000; Woodruff et al., 2006), the left-parietal old/new effect (Curran, 2004; Duzel et al., 1997; Wilding & Rugg, 1996) and the LPN (LPN; Herron, 2007; Johansson & Mecklinger, 2003). These windows were respectively 300-500 ms, 500-800 ms, 600-1200 ms and 1200-1600 ms. The last two windows were used to capture the LPN. The electrode selection and partitioning were the same as in Experiment 4 (Figure 6.2). The spline maps of the old/new effects for the Self and a Distant Other across the four time windows are presented in Figure 7.5.

##### *7.3.2.2.1 Mean amplitudes in the early time windows: 300-500 ms and 500-800 ms*

Mean amplitudes in the 300-500 ms and 500-800 ms intervals were calculated across electrodes at the six regions of the scalp and submitted to a repeated-measures ANOVA employing factors of Reference Person (Self vs. Distant Other), Memory (Remember vs. Correct Rejections), Time Window (300-500 ms vs. 500-800 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The results revealed no significant interactions between Reference Person and Memory[35]. The same was true when planned comparisons were conducted on bilaterally frontal regions around 300-500 ms[36] and left-parietal region around 500-800 ms[37].

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[35] The interactions between Reference Person and Memory ($F(1, 23) = .553$, $\eta_p^2 = .023$, $p = .463$), between Time Window, Reference Person and Memory ($F(1, 23) = .271$, $\eta_p^2 = .012$, $p = .606$), between Caudality, Reference Person and Memory ($F(1.2, 26.6) = .177$, $\eta_p^2 = .008$, $p = .713$), between Hemisphere, Reference Person and Memory ($F(1, 23) = .671$, $\eta_p^2 = .028$, $p = .419$), between Time Window, Caudality, Reference Person and Memory ($F(1.2, 28.7) = 1.523$, $\eta_p^2 = .060$, $p = .233$), between Time Window, Hemisphere, Reference Person and Memory ($F(1, 23) = 1.133$, $\eta_p^2 = .047$, $p = .180$), between Caudality, Hemisphere, Reference Person and Memory ($F(1.8, 40.9) = .948$, $\eta_p^2 = .040$, $p = .384$) and between Time Window, Caudality, Hemisphere, Reference Person and Memory ($F(1.7, 38.6) = .290$, $\eta_p^2 = .013$, $p = .710$) were not significant.

[36] During 300-500 ms, interactions between Reference Person and Memory were not significant at left-frontal ($F(1, 23) = .243$, $\eta_p^2 = .010$, $p = .625$) or right-frontal ($F(1, 23) = .169$, $\eta_p^2 = .007$, $p = .684$).

[37] The interaction between Reference Person and Memory was not significant during 500-800 ms at left-parietal region ($F(1, 23) = 1.329$, $\eta_p^2 = .055$, $p = .262$).

The interaction between Time Window, Caudality, Hemisphere and Memory was also significant (F(1.5, 34.4) = 4.528, $\eta_p^2$ = .166, p = .027)[38], but no further significant Memory effect was found during 300-500 ms[39] or 500-800 ms[40].

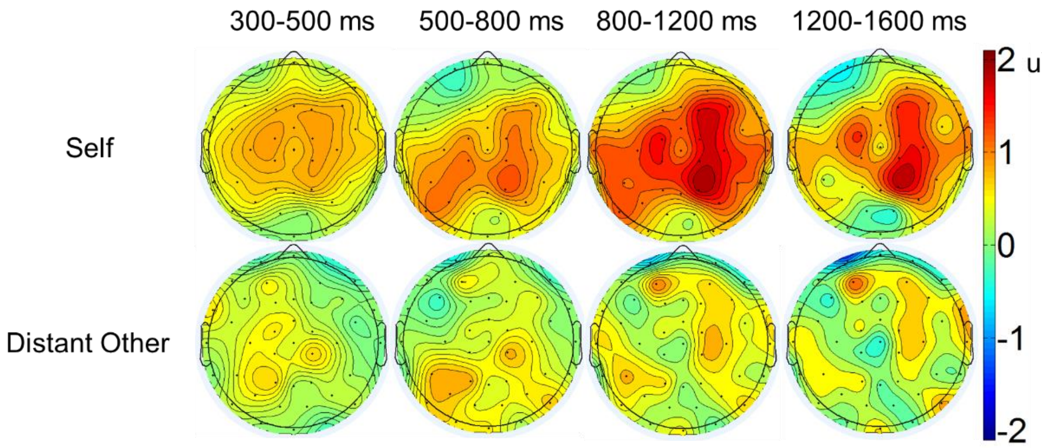

*Figure 7.5. Spline maps showing the ERP differences between test items given remember and correct rejection responses for the self (top) and a distant other (bottom) for the four time windows that were analysed (300-500 ms, 500-800 ms, 800-1200 ms and 1200-1600 ms).*

### *7.3.2.2.2 Mean amplitudes in the late time windows: 800-1200 ms and 1200-1600 ms*

Similar to the analyses in the previous section, the mean amplitudes in the 800-1200 ms and 1200-1600 ms windows were submitted to a repeated measures ANOVA employing factors of Reference Person (Self vs. Distant Other), Memory (Remember vs. Correct Rejections), Time Window (800-1200 ms vs. 1200-1600 ms), Hemisphere (Left vs. Right) and Caudality (Frontal vs. Central vs. Parietal). The results did not indicate significant effects related to Memory[41].

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[38] The main effect of Memory (F(1, 23) = .500, $\eta_p^2$ = .021, p = .485), interactions between Time Window and Memory (F(1, 23) = .206, $\eta_p^2$ = .009, p = .653), between Caudality and Memory (F(1.2, 27.1) = 1.107, $\eta_p^2$ = .047, p = .314), between Hemisphere and Memory (F(1, 23) = .001, $\eta_p^2$ < .001, p = .108), between Time Window, Caudality and Memory (F(1.2, 27.0) = .820, $\eta_p^2$ = .035, p = .389), between Time Window, Hemisphere and Memory (F(1, 23) = 3.195, $\eta_p^2$ = .122, p = .087) and between Caudality, Hemisphere and Memory (F(1.8, 41.2) = .737, $\eta_p^2$ = .031, p = .469) were not significant.

[39] During 300-500 ms, the main effect of Memory (F(1, 23) = .173, $\eta_p^2$ = .007, p = .680), interactions between Caudality and Memory (F(1.1, 25.0) = .453, $\eta_p^2$ = .020, p = .521), between Hemisphere and Memory (F(1, 23) = .437, $\eta_p^2$ = .019, p = .513) and between Caudality, Hemisphere and Memory (F(1.6, 36.8) = .187, $\eta_p^2$ = .008, p = .781) were not significant.

[40] During 500-800 ms, the main effect of Memory (F(1, 23) = .883, $\eta_p^2$ = .037, p = .335), interactions between Caudality and Memory (F(1.4, 31.4) = 2.109, $\eta_p^2$ = .086, p = .151), between Hemisphere and Memory (F(1, 23) = .429, $\eta_p^2$ = .018, p = .517) and between Caudality, Hemisphere and Memory (F(1.8, 42.5) = 2.181, $\eta_p^2$ = .084, p = .129) were not significant.

[41] The main effect of Memory (F(1, 23) = 3.802, $\eta_p^2$ = .142, p = .064), interactions between Time Window and Memory (F(1, 23) = .240, $\eta_p^2$ = .010, p = .628), between Caudality and Memory (F(1.6, 37.7) = 1.967, $\eta_p^2$ = .077, p = .161), between Hemisphere and Memory (F(1, 23) = 2.135, $\eta_p^2$ = .085, p = .158), between Time Window, Caudality and Memory (F(1.2, 27.1) = 2.001, $\eta_p^2$ = .081, p = .168), between Time Window, Hemisphere and Memory (F(1, 23) = 1.432, $\eta_p^2$ = .059, p = .245), between Caudality, Hemisphere and Memory (F(1.9, 43.4) = .424, $\eta_p^2$ = .018, p = .645), between Time Window, Caudality, Hemisphere and Memory (F(1.9, 44.0) = .677, $\eta_p^2$ = .029, p = .505), between Reference Person and Memory (F(1, 23) = 1.524, $\eta_p^2$ = .062, p = .230), between Time Window, Reference Person and Memory (F(1, 23) = .413, $\eta_p^2$ = .018, p = .525), between Caudality, Reference Person and Memory (F(1.2, 28.2) = .283, $\eta_p^2$ = .012, p = .644), between Hemisphere, Reference Person and Memory (F(1, 23) = .685, $\eta_p^2$ = .029, p = .414), between Time Window, Caudality, Reference Person and Memory (F(1.2, 27.4) = .630, $\eta_p^2$ = .027, p = .459), between Time Window, Hemisphere, Reference

Planned comparisons on the parietal regions for the LPN suggested no significant effects related to Memory were found at any time windows[42].

### 7.3.2.3 Summary

Surprisingly, the statistical analysis involving partitions on the scalp did not suggest any significant effects relevant to subsequent memory effect during encoding or old/new effect during retrieval. Planned comparisons suggested a trend of late subsequent memory effect (600-1100 ms) for the self at left frontal region. No old/new effects were found during retrieval.

## 7.3.3 Oscillatory analysis

The oscillatory analyses were performed in the same way as in Experiment 4: a single epoch was used to represent the power changes during the pre- and post-stimulus intervals during encoding (see the timeline in the figures below). The pre-stimulus interval spanned from 0 to 1500 ms and the post-stimulus interval from 1500 to 2000 ms.

### 7.3.3.1 Study phase

#### *7.3.3.1.1 Theta band activities*

A significant, widespread theta power decrease was found for adjectives given a Remember judgment in the later recognition memory test as compared to adjectives judged as Known or New. This decrease occurred between 900 and 1800 ms after adjective onset (Figure 7.6). Importantly, a significant interaction between the reference person and subsequent memory was found during the 300 ms intervals before and after adjective onset (Figure 7.7). Followed-up subsidiary analyses indicated a significant power decrease over posterior scalp sites for items that were subsequently remembered for the Distant Other, but not for the Self.

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Person and Memory (F(1, 23) = 3.944, $\eta_p^2$ = .148, p = .058), between Caudality, Hemisphere, Reference Person and Memory (F(1.8, 42.4) = 1.943, $\eta_p^2$ = .076, p = .159) and between Time Window, Caudality, Hemisphere, Reference Person and Memory (F(1.5, 33.8) = .600, $\eta_p^2$ = .026, p = .5035) were not significant.

[42] The main effects of Memory at 800-1200 ms at left-parietal (F(1, 23) = 1.483, $\eta_p^2$ = .061, p = .236) and right-parietal (F(1, 23) = 1.999, $\eta_p^2$ = .080, p = .171) regions and at 1200-1800 ms at left-parietal (F(1, 23) = .044, $\eta_p^2$ = .002, p = .836) and right-parietal (F(1, 23) = .734, $\eta_p^2$ = .031, p = .398) regions were not significant.

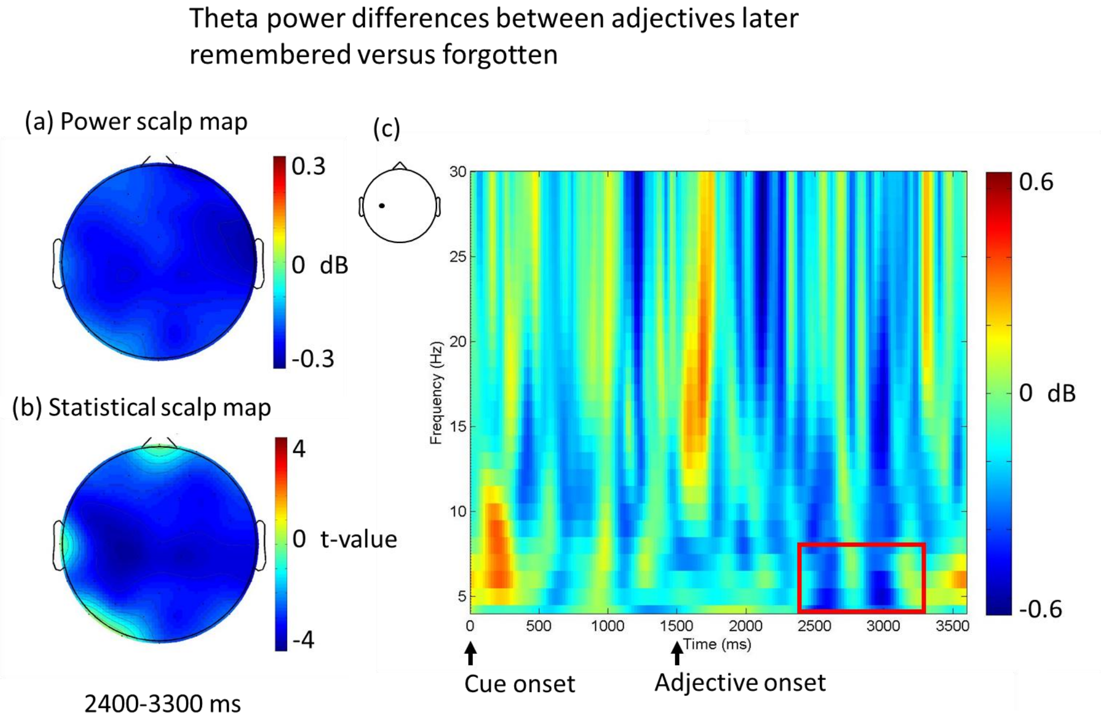
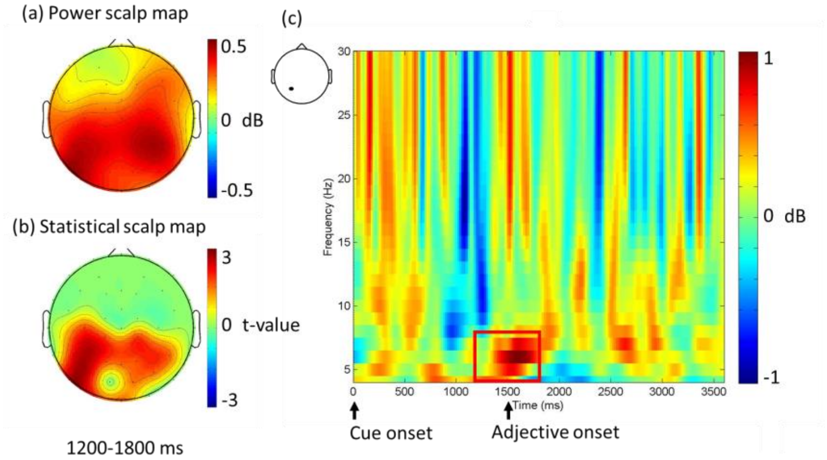


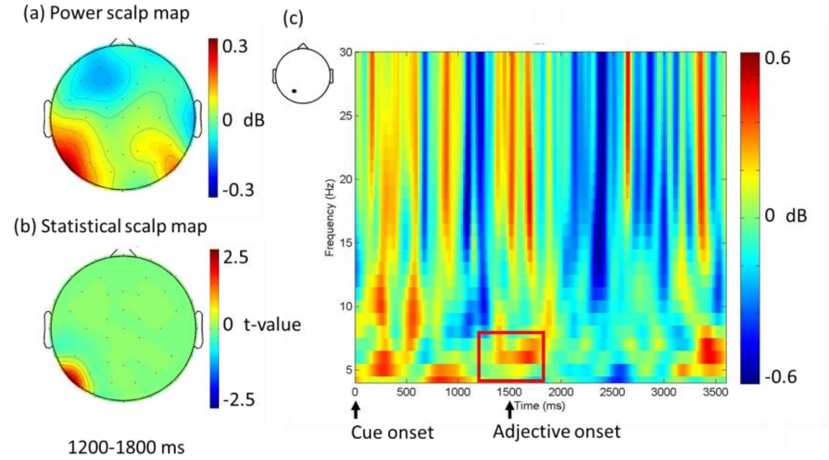
*Figure 7.6. Encoding-related activity in the theta (4-7 Hz) power range during the study phase, collapsed across the self and a distant other. (a) Scalp map showing the difference in theta power between adjectives that were given a Remember judgment during the recognition memory test and adjectives later judged to be Known or New. (b) Statistical scalp map corresponding to the power changes shown in (a). (c) Time-frequency plot of power differences at a left-parietal electrode site (17). A significant decrease in theta power occurred between 900 and 1800 after the onset of the adjective (2400-3300 ms after cue onset), as indicated with the red square.*

Theta power differences between adjectives later remembered versus forgotten

(A) Difference in encoding-related activity between Self and Distant Other



(B) Self encoding-related activity (Remember vs. Miss/Know)



(C) Distant Other encoding-related activity (Remember vs. Miss/Know)

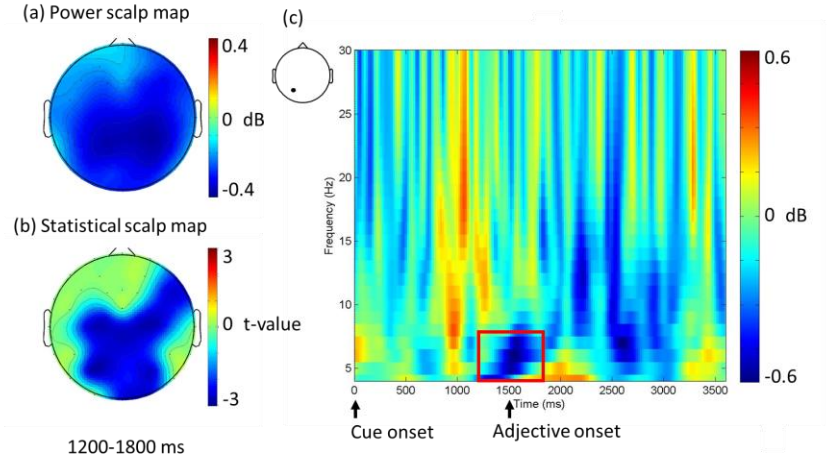
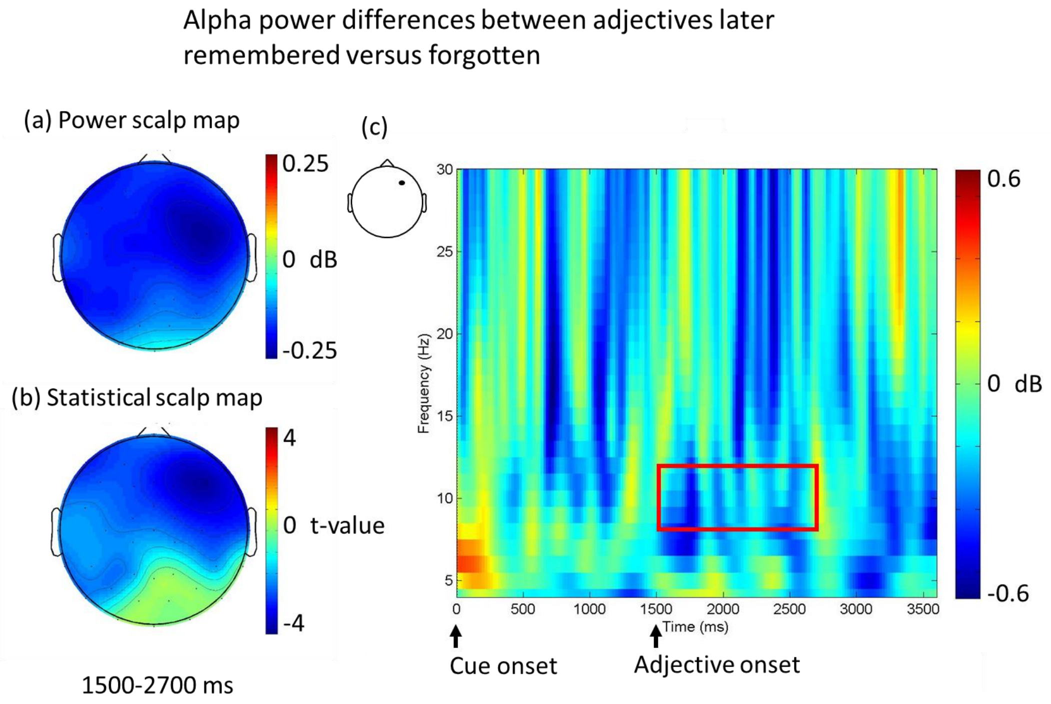


*Figure 7.7. The theta (4-7 Hz) power change (a) and statistical scalp maps (b) showing the difference of encoding-related activity between Self and Close during -300-300 ms after adjective onset (1200-1800 ms after cue onset) (A). The power difference of a right-frontal electrode (29) is shown in (c), the red square shows the statistically significant frequency band and time window. The difference between Remember and Miss/Know for Self (B) and Distant Other (C) in the same time window. The red square shows the statistically significant frequency band and time window.*

### 7.3.3.1.2 Alpha band activities

A long-lasting, right-frontal alpha power decrease was found for items that were later remembered versus forgotten in the 0-1200 ms interval after adjective onset (1500-2700 ms after cue onset, see Figure 7.8). This encoding-related activity did not interact with type of reference person (Self vs. Distant Other) at any electrode or time window.



Alpha power differences between adjectives later remembered versus forgotten

*Figure 7.8. The alpha (8-12 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Miss/Know during 0-1200 ms after adjective onset (1500-2700 ms after cue onset), with levels of Reference Person collapsed. The power difference of a right-frontal electrode (22) is shown in (c), the red square shows the statistical frequency band and time window.*

### 7.3.3.1.3 Beta band activities

A widespread decrease in beta power was found when comparing items that were later remembered as opposed to forgotten in the 300-900 ms interval after adjective onset (1800-2400 ms after cue onset, see Figure 7.9). As before, the interaction between subsequent memory and the type of person about which a decision had to be made (Self vs. Distant Other) was not significant at any electrode or time window.

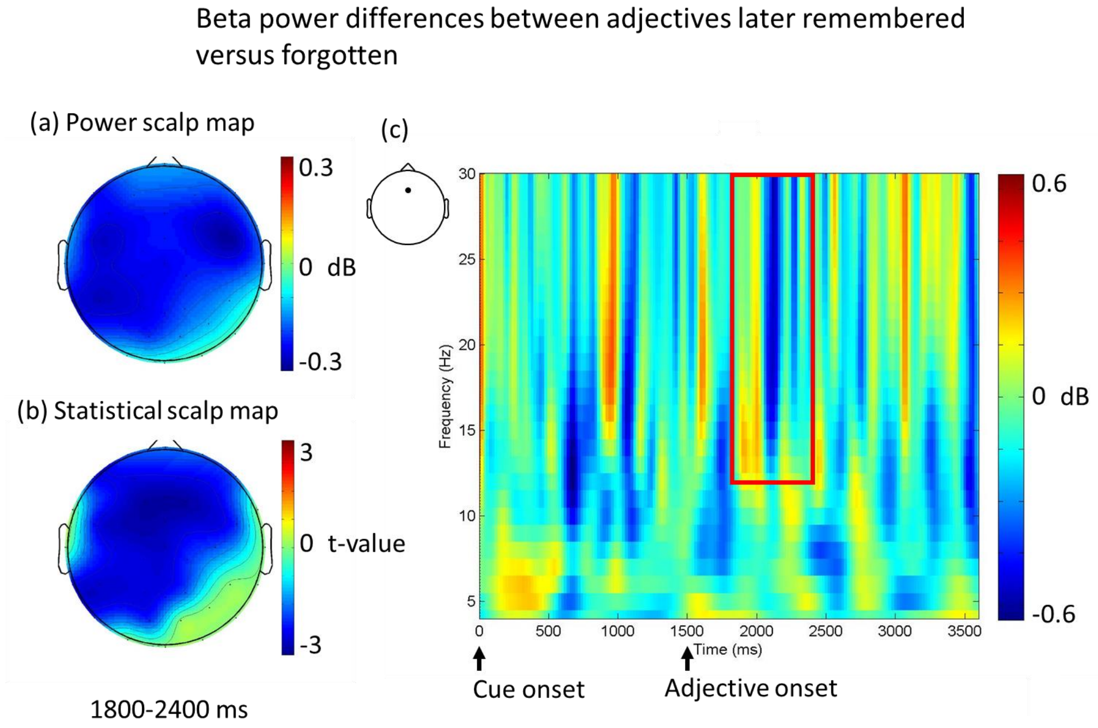


*Figure 7.9. The beta (13-30 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Miss/Know during 300-900 ms after adjective onset (1800-2400 ms after cue onset), with levels of Reference Person collapsed. The power difference of a mid-frontal electrode (8) is shown in (c), the red square shows the statistical frequency band and time window.*

### 7.3.3.2 Test phase

#### *7.3.3.2.1 Alpha band activities*

During the recognition memory test, oscillatory brain activity differed depending on whether an adjective was successfully remembered. A decrease in posterior alpha power was found in the 900-1800 ms interval after the onset of adjectives that were recollected as opposed to correctly rejected (Figure 7.10). This decrease did not differ across adjectives that were processed in relation to the self or a distant other.

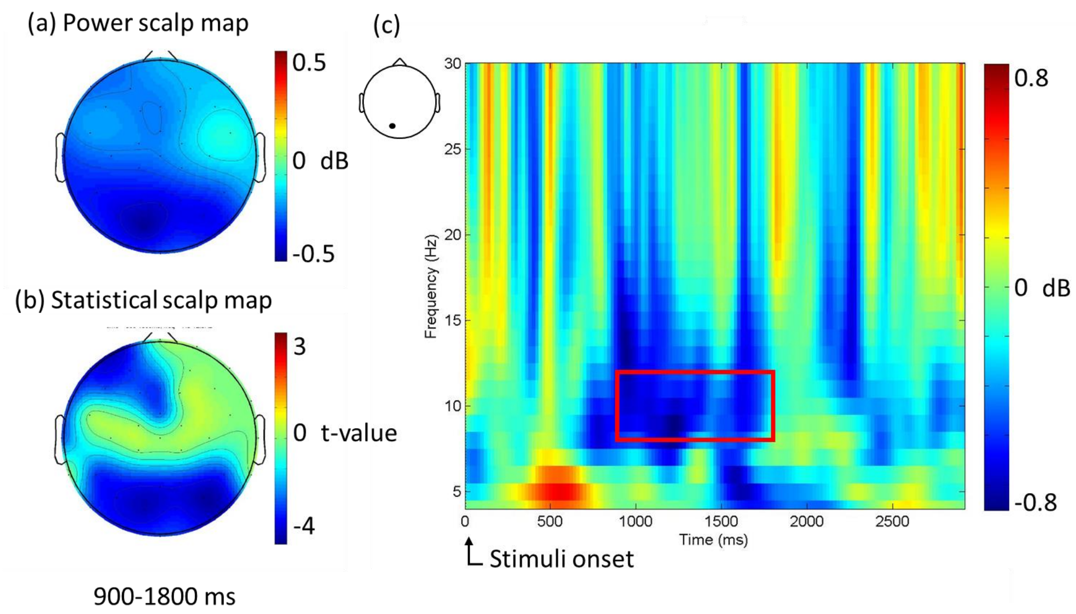

Alpha power difference between Remember and Correct Rejection

*Figure 7.10. The alpha (8-12 Hz) power change (a) and statistical scalp maps (b) showing the difference between Remember and Correct Rejections during 900-1800 ms after test item onset, with levels of Self collapsed. The power difference of a posterior electrode (28) is shown in (c), the red square shows the statistical frequency band and time window.*

#### *7.3.3.2.2 Theta and Beta activities*

No significant old/new effects were found in the theta and beta frequency bands.

### 7.3.3.3 Summary

To summarise the effects seen in oscillatory brain activity, a number of power decreases were observed during the study phase after the onset of adjectives that were later remembered. Encoding-related activity was observed as a long-lasting and widespread decrease in theta power between 900 and 1800 ms after adjective onset, a right-frontal decrease in alpha power between 0 and 1200 ms after adjective onset and a widespread decrease in beta power between 300 and 900 ms after adjective onset. These differences were found for items that were subsequently recollected versus forgotten. Importantly, a subsequent memory effect that was sensitive to the person about which a decision had to be made was also found. Theta power over posterior scalp sites decreased at around the time an item occurred that had to be encoded in relation to a distant other but not the self (-/+300 ms around adjective onset). During retrieval, the only old/new effect that occurred was a frontal alpha power decrease between 900 and 1800 ms after items that were successfully recollected.

## 7.4 Discussion

Experiment 5 was designed to address the electrophysiological activities associated with encoding and retrieving information regarding oneself and a distant other. The issues were investigated via subsequent memory and old/new effects in ERPs and oscillatory power.

As expected, the behavioural results showed a robust SRE in that information pertaining to the self was remembered better than information pertaining to a distant other. This effect was larger for recollection than familiarity and is consistent with previous experiments in this thesis and past studies on the SRE (Conway & Dewhurst, 1995; Leshikar et al., 2015). Presumably it reflects that the self enables the mobilisation of processes that facilitate memory encoding, for example, by accessing self-schema (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997). Unsurprisingly, the reaction times during encoding also suggest that information encoded in relation to the self is processed faster than information encoded in relation to a distant other, particularly when emotional (positive and negative) items are involved. The behavioural findings in this experiment further replicated the observations in the previous experiment in this thesis.

Encoding information related to a distant other, on the other hand, seemed to employ additional preparation than the self during encoding to complete the task in hand. In this experiment, a significant subsequent memory effect was observed in the form of a posterior theta power decrease around item onset. This effect was only prominent for items encoded in relation to a distant other and not the self. The functional significance of this theta power decrease is not clear. In the literature, theta oscillations have mainly been reported to increase instead of decrease during encoding (e.g., M. J. Gruber et al., 2013; Guderian et al., 2009). Nevertheless, it is likely that participants employed a preparatory process to deal with the trait judgments for a distant other during encoding to allow better memory formation. This process might be elicited by the cue and carry over until after the presentation of the to-be-encoded target. This proposal is based on the observation of a posterior theta power decrease that started before adjective onset (~-300 ms) and ended shortly after the onset of the adjective (~300 ms). For information encoded in relation to the self, such theta power decrease during preparation was not observed, while a better memory performance than a distant other was achieved.

The encoding-related decreases in theta power found in Experiment 4 were interpreted as reflecting the formation of associations between an item and its context, which leads to better later memory (Greenberg et al., 2015; Long et al., 2014). Decreases in theta power were also found in the current experiment. During encoding, a widespread theta power decrease occurred for items that were subsequently remembered, regardless of whether the items were encoded in relation to the self or a distant other. In addition, a right frontal alpha power decrease was found for items subsequently remembered. This decrease may reflect semantic encoding (Hanslmayr et al., 2009). Interestingly, the encoding-related decrease in the final power band, beta, was found for both the self and a distant other in the current experiment. In Experiment 4, it was limited to the close other (see Table 7.5 for comparisons between Experiments 4 and 5). In the literature, beta power decreases during memory formation have been linked to semantic and conceptual processing of the memory materials (Hanslmayr & Staudigl, 2014; Jensen & Mazaheri, 2010; Klimesch, 2012). The beta power decrease observed here for the self and a distant other might reflect such processes. The fact that the beta power decrease was only found for the close other in Experiment 4 was thought to reflect the retrieval of an episode with a close other. This was not thought to be necessary when judging traits in relation to the self, which can be achieved by accessing established knowledge about the self (i.e. self-schema) instead of engaging in online evaluations.

In the current experiment, however, both the self and a distant other showed such beta power decreases. A possible explanation for these apparent inconsistent findings is that self-referenced encoding is context dependent. Brain activities that support self-referenced encoding may depend on which other encoding condition is intermixed with decisions about the self. It is possible that participants adopted additional top-down strategies to ensure that knowledge of the self can be accessed relatively effortlessly when also encoding information about distant others. The encoding-related processes used for self-relevant information may differ depending on whether decisions about the self have to be made alongside decisions about a close or distant other. The brain activities related to successful memory formation and retrieval may differ accordingly. This possibility may also explain the surprisingly weak subsequent memory and old/new effects found in Experiment 5. Alternatively, the weak subsequent memory and old/new effects may also be due to the overall low memory accuracies across experiments. The materials used in the experiments are abstract adjectives which may result in higher difficulties to memorise than concrete words (Strozak, Bird, Corby, Frishkoff, & Curran, 2016) or nouns (Maki & McCaul, 1985). Another possible reason of the weak old/new effects can be related to the sample size and the power being insufficient in the experiment. Nevertheless, in this experiment, a significant old/new effect was however found in the form of an alpha power decrease, possibly reflecting the functional inhibition of task-irrelevant activations during memory retrieval (Waldhauser et al., 2012).

The findings of Experiment 5 suggest that oscillatory activities supporting encoding and retrieval of information pertaining to the self and a familiar but distant other are in part dissociable, though the closeness of the distant was not measure directly. Together with the findings of the self and a close other in Experiment 4, it may suggest that the information associated with the self is processed with temporal- and spatial-dissociable neuronal populations at encoding and retrieval. The findings suggest that closeness to others cannot exclusively account for the qualitatively different brain activities of the self-reference effect. Instead, the self seems to be a more important factor than closeness to others in the SRE. Further discussion of these findings is provided in the next chapter, which offers a general discussion of the experiments reported in this thesis.

*Table 7.5. Summary of behavioural and EEG findings in Experiments 4 and 5.*

| | Experiment 4<br>Self vs. Close Other | Experiment 5<br>Self vs. Distant Other |
|---|---|---|
| Behavioural SRE | Yes, recollection > familiarity | Yes, recollection > familiarity |
| ERPs | | |
| Pre-stimulus SME | No | No |
| Post-stimulus SME | Right-frontal, 200-1900 ms | Self only, left-frontal, 600-1100 ms * |
| Retrieval | | |
| Mid-frontal and left-parietal effects | Self only, 300-500 ms and 500-800 ms | No |
| Late-posterior negativity | Close Other only, 800-1200 ms and 1200-1600 ms | No |
| Oscillatory activities | | |
| Pre-stimulus SME | No | Distant Other only, parietal theta power decrease around adjective onset (-/+300 ms) |
| Post-stimulus SME | | |
| Theta power decrease | Frontal, 1500-2100 ms | Widespread, 900-1800 ms |
| Alpha power decrease | Widespread, 600-2000 ms | Right-frontal, 0-1200 ms |
| Beta power decrease | Close Other only, widespread, 600-1200 ms | Widespread, 300-900 ms |
| Retrieval | | |
| Theta power decrease | Parietal, 900-1500 ms | No |
| Alpha power decrease | Frontal, 600-1200 ms | Frontal, 900-1800 ms |
| Beta power decrease | Frontal, 600-1200 ms | No |

*based on planned comparisons

# Chapter 8. General discussion

In this final chapter, I will summarise and discuss the findings of the thesis. I will first give an overview of the findings and explain how they compare with and add to previous studies in the literature. Then, I will cover more general issues in psychology and cognitive neuroscience that are relevant to the research questions of the thesis, before presenting the final conclusions.

## 8.1 Overview of the findings

The empirical work presented in this thesis was developed to address two research questions related to the role of the self in episodic memory:

1. What is the effect of closeness to others on the memory advantage seen for self-reference information (the SRE)?
2. What are the electrophysiological activities associated with encoding and retrieving information regarding oneself?

The first research question was whether the self or closeness to others is the key factor underlying the SRE. The question concerns whether there is something special about the self or that the SRE can be explained by superior closeness to oneself. This question was addressed with three behavioural experiments. Experiment 1 addressed this issue by creating conditions in which the self was compared with the closest and most familiar other to a participant. In addition, both were compared with a distant other who had a comparable level of familiarity. The results showed a significant SRE for the self when compared to both a close other and a distant other. The memory accuracies of a close other and a distant other were not different. Experiment 2 was designed to address the types of memory supporting the SRE with source memory tasks. It was further confirmed that the superior memory for the self was due to associations created during encoding between the memory content and the self. Experiment 3 investigated the effect of individual differences on the SRE with self-esteem and Big-Five personality questionnaires. Participants with low openness traits showed a significant SRE on recollection to neutral items. Participants with high extraversion scores also rated themselves more consistent with positive items than a distant other, while participants with high neuroticism scores rated themselves more consistent with negative items than a distant other. However, no evidence showing that individual differences has effects on the SRE.

The second research question was addressed with EEG in Experiments 4 and 5. Experiment 4 investigated the electrophysiological activities during the intervals before and after a to-be-encoded stimulus and the interval after a test probe. These activities were investigated for the self and a close other. Experiment 5 investigated the same types of brain activities, but this time the self was compared with a distant other. Both experiments found specific activities for the self, a close other and a distant other at different stages of memory. The results also suggest that the memory-related brain activities supporting the self are context-dependent in that they differ depending on who else decisions need to be made about.

## 8.2 Electrophysiological activities of the self, a close other and a distant other

To the best of my knowledge, this thesis is relatively novel in that it reveals the electrophysiological correlates of self- and other-referenced information in episodic memory. Prior to this thesis, few studies addressed the electrophysiological correlates of self-referencing in episodic memory (e.g., Dulas et al., 2011; Mu & Han, 2010) but none of them fully addressed the electrophysiological mechanisms of self-referencing across episodic memory encoding and retrieval. For instance, in Mu and Han (2010), the oscillation activities during self-referencing encoding was investigated, but this was not addressed in the context of whether the memory was encoded successfully. In another case, Dulas et al. (2011) investigated the ERPs during retrieval in the context of the SRE. However, the discussion was addressed more with the effects of ageing in episodic memory, instead of the nature of the SRE. The results of the current thesis added up to the gaps in the literature, which are crucial for updating the knowledge of why the self is effective in episodic memory.

Experiments 4 and 5 found that the brain activities that support the encoding and retrieval of information about oneself depend on the type of other person that is used as a comparison point. When information pertaining to the self was retrieved along with information pertaining to a close other, the successful retrieval of the two kinds of information relied on spatially-dissociable neural populations at different time courses of retrieval. Moreover, beta oscillations during encoding suggested that additional conceptual processes were employed to process information about a close other but not the self. The two kinds of information seem processed with at least distinct neuronal signature during encoding and retrieval. Interestingly, when the information about oneself was encoded and retrieved relative to a distant other, it seemed that the self was processed in a different way. It was found that compared to a distant other, the encoding and retrieval of the self were associated with a small subsequent memory effect. On the other hand, the encoding of information about a distant other was associated with a parietal theta power decrease leading up to the onset of the memory target. This decrease was not found for the self. It is not clear what factors affect the neural mechanisms used for the self in different encoding and retrieval contexts. However, it is worth noting that both experiments showed significant behavioural SREs with a larger effect on recollection than familiarity. This has also been found in some of the previous studies (e.g., Gutchess et al., 2015; Leblond et al., 2016; Leshikar et al., 2015; Symons & Johnson, 1997). This finding might reflect that even the brain activities supporting the self are modulated by the context, the efficiency and effectiveness of the recollection to the self is relatively independent from the context change.. This interpretation is consistent with the faster response times and memory accuracies for the self relative to both a close other and a distant other during encoding and retrieval.

More generally, the brain activities in this thesis suggest that it is not clear cut to conclude that the self is necessarily processed with specialised neural populations. Instead, it seems that the information processing of oneself partly involves a mechanism that considers the self and the other person simultaneously, for example, via a social comparison (Brehm et al., 2005; Corcoran et al., 2011; Festinger, 1954). In this case, the evaluation of the self is affected by the other person in the context. This idea is also in line with the argument that when looking at the SRE, considering the experimental design and context is necessary (Klein, 2012).

The findings of variable old/new effects across the self and close/distant others do not agree with a previous study that suggested that self-referencing does not affect the mid-frontal and left-parietal old/new effects (Dulas et al., 2011). In Dulas et al. (2011), they found that young and old groups of participants showed significant old/new effects regardless of whether the information was encoded in relation to the self or in a semantic task. However, their study is different from the current one in at least two aspects. First, the self-reference task they used involved asking participants to judge whether a picture of a concrete object was pleasant to themselves. This differs from a self-descriptive task that is used more often in the literature and in this thesis. The different encoding tasks may have led to different results. Second, a more crucial difference is that self-referential memory was compared with a semantic control task (“is it a common object?”), instead of referencing to another person. The different bases of comparisons raise concerns about comparing the self with a semantic encoding task; these may reflect fundamental differences between the two types of control tasks, instead of reflecting the differences between processing information to oneself and another. On the other hand, Mu and Han (2010) found that superior self-referenced memory accuracy was associated with a left-frontal theta power increase when compared to a friend-referenced or control judgment (about the valence of the stimuli). This finding is consistent with the large majority of findings in the literature that increases in theta power are often related to successful memory retrieval (e.g., Guderian & Duzel, 2005; Nyhus & Curran, 2010). However, there do not seem to be any studies that report the association between decreases in theta power and superior memory accuracy as found in this. There has been literature suggesting that theta power decrease was associated with successful memory encoding (Greenberg et al., 2015; Long et al., 2014), particularly when forming associations between memory items (Greenberg et al., 2015). It is not clear how the theta power decrease during successful encoding relates to the decreases during successful retrieval, but the theta power decrease might also connect to retrieving episodes with rich details.

It is also worth noting that the late-posterior negativity (the 'LPN'; Herron, 2007; Johansson & Mecklinger, 2003) was found when the information pertained to a close other was retrieved alongside with the information pertained to the self. Such finding was interpreted as retrieving the information pertained to a close other involved additional top-down search and post-retrieval maintenance processes, hence this pattern was not found for the information pertained to the self. Interestingly, the LPN was not found for the information pertained to a distant other, while the information was also retrieved alongside with the information pertained to the self. These findings may not seem compatible with a previous study suggesting that the LPN is enhanced when memory retrieval is difficult (Herron & Wilding, 2005; see Mecklinger, Rosburg, & Johansson, 2016 for review), as the retrieval difficulty should be higher for the information pertained to a distant other than a close other given the higher memory accuracy for the latter. Indeed, if the LPN is reflected by the difficulties of retrieval, the LPN for the information pertained to a distant other should be larger than the information pertained to a close other. However, it has also been suggested that the LPN likely reflects relatively complex combinations of episodes, for example, the amount of information retrieved, the number of memory attributes related or the specificity with the person retrieving memory (Mecklinger et al., 2016). In this case, the LPN is more likely to be affected by the amount of information retrieved. In the case of a close other, a certain number of episodes might be recollected to support the recognition memory decision due to the emotional attachment and the high degree of involvement in the participant’s daily life, hence enhanced the LPN observed. On the other hand, the recognition memory decisions to the self might be contributed by accessing the self-schema (Klein, 2012; Klein & Loftus, 1988; Symons & Johnson, 1997), as this can be an efficient option to access self-relevant information, whereas the recognition memory decision to a distant other might be supported by retrieving the information linked to the adjectives but not as rich as a close other.

## 8.3 The role of the self in episodic memory

Past studies have demonstrated that the self is effective in memory encoding (Klein, 2012; Symons & Johnson, 1997) and is able to compensate for memory decline due to ageing (Dulas et al., 2011; Gutchess et al., 2015; Leshikar et al., 2015). However, the theoretical accounts as to why the self is effective in memory encoding have been diverse in the literature. For example, early studies considered whether accessing the self-construct underlies the benefit seen in memory encoding (Maki & McCaul, 1985). Later studies suggested that self-referencing is beneficial to memory encoding due to it facilitating both elaborative and organisational processes, as compared to other-referencing and semantic control tasks which benefit organisational (e.g., 'does the adjective describe a close other?') or elaborative (e.g., 'is it a positive or a negative trait?') processes in isolation (Klein & Loftus, 1988; Symons & Johnson, 1997). More recent accounts considered the SRE as a family of effects instead of a single phenomenon (Klein, 2012). All these studies tried to address the reason why the self is effective in memory encoding. However, no conclusive agreements have been made yet.

One of the major differences between the current thesis and past studies investigating the SRE is that in this thesis, the self, a close other and a distant other share comparable levels of familiarity. Familiarity is known to typically be confounded with closeness in the literature, and it has thus not been possible to discern which of the two underlies the SRE (Symons & Johnson, 1997). Across the five experiments in this thesis, the self consistently elicited better memory performance than a close other or a distant other. These findings suggest that the levels of familiarity cannot exclusively explain the SRE in the literature (cf. Keenan & Baillet, 1980; Maki & McCaul, 1985). In addition, this thesis demonstrates that even when the other person is someone who is closest to the participant, information referenced to oneself still elicits better memory performance. This finding indicates that closeness to others is not necessarily a key factor underlying the SRE. Instead, the findings suggest that the self is special compared to others, regardless of the levels of familiarity and closeness. The self provides an effective and efficient tool for encoding.

It has been suggested that the self is beneficial to memory encoding due to the self employing additional elaborative processes compared to others (Klein & Loftus, 1988; Symons & Johnson, 1997). Interestingly, the encoding-related brain activities observed in this thesis suggest that additional oscillatory activities associated with conceptual processing are employed to encode information about a close other and a distant other instead of the self. Thus, from a neural perspective there seems to be something special about processing others and not the self. Having said that, it can be speculated that the self is a special interface with the ability to mobilise cognitive processes more efficiently, without the need to employ additional cognitive processes. One example of this might be the access to self-schema (Markus & Smith, 1981) as a quick and efficient route to identify the output demanded by self-referencing tasks. This proposal is similar to the literature that argues that the self involves a binding function that can link representations effectively (e.g., Sui, 2016; Sui & Humphreys, 2015) (but see Lane et al., 2016) or that the self is a specialised form of attention that can bias cognitive resources (e.g., Conway et al., 2016; Turk et al., 2011).

It is worth noting that some of the past studies suggest that self-referencing is effective only during encoding but not retrieval. This is because self-referencing can modulate activations in the ventral mPFC and hippocampus of adolescents during encoding (Degeilh et al., 2015). However, this argument is not compatible with the electrophysiological findings in this thesis, which showed that brain activities can be modulated by self-referencing during both encoding and retrieval. In addition, reaction times during retrieval showed a benefit for information pertaining to the self. These findings suggest that the effect of self-referencing is not limited to encoding but can carry forward to memory retrieval.

## 8.4 Closeness to others

Whether the self and others are on a continuous dimension or differ in a discrete manner has not yet been agreed in the literature. Some researchers suggest that the self often gets confused with a close other (e.g., Allan et al., 2017; Aron & Aron, 1986). However, other researchers argue that close others will never become the self as self-awareness and sense of agency are not possessed in any form when making decisions about others (Decety & Sommerville, 2003). Accordingly the brain regions involved in self-related processing are thought to be distinct from regions involved in other-related processing (Bergström et al., 2015; de Caso et al., 2017; Kelley et al., 2002).

These arguments in the literature are related to the findings in this thesis in that the close other used in this thesis was specifically chosen to be the closest person to each participant. If the self and others are on a continuous dimension of closeness, this person should be the closest point to the self and show small or no differences to the self, while both being different from a distant other (e.g., Czienskowski & Giljohann, 2002). Interestingly, in the context of memory, a consistent pattern emerged across all the experiments in the thesis that information pertaining to the self was always remembered better than information pertaining to a close or distant other. Together with the fact that the brain activities for the self and a close other were dissociable in terms of their time of occurrence and distribution across the scalp, it seems that the findings support the argument that a close other will never become the same as the self. In turn, this supports the idea that the self and others are on discrete dimensions of closeness.

It is still possible that the memory differences observed between the self and a close other are due to degrees of closeness rather than distinct categories, or at least have a contribution from degrees of closeness. This might be because a close other who is subjectively as familiar and close as the self, the close other is likely never truly as close as the self. However, this alternative interpretation is only supported if a less close (distant) other shows different patterns from a close other. Indeed, in the thesis, the recollection of a close other and a distant other never differed from each other. The ERP results related to recollection also showed no evidence of significant left-parietal old/new effects. This may suggest that closeness only has a small or no effect on recollection, as compared to factors that are exclusively possessed by the self, such as self-awareness and the subjective experience of being responsible for one's own actions and thoughts (David, Newen, & Vogeley, 2008; Klein, 2012).

## 8.5 Emotion and episodic memory

In the literature, it is unclear to what extent emotional events can boost memory. Although it is commonly thought that emotional events are always remembered better, there has in fact been a debate and lack of agreement. There have certainly been studies that suggest that emotional information can facilitate memory of emotional events as compared to neutral events (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). This finding has been interpreted as suggesting that emotion enhances memory due to more cognitive resources being allocated to emotional events (Nairne, 2010), 'starving' resources allocated to neutral items when items are intermixed (Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014). However, other studies show no evidence for better memory for emotional items (e.g., Bisby & Burgess, 2014; Cook et al., 2007; MacKenzie et al., 2015) or for emotion boosting the subjective feeling of remembering but not objective memory accuracy (Sharot et al., 2004). In addition, some self-reference effect studies show that positive emotional events give rise to greater source memory accuracy for the self versus others (Doerksen & Shimamura, 2001; Yick et al., 2015). This finding was interpreted to reflect the tendency to keep a positive self-image, enhancing memory for positive events that relate to the self (D'Argembeau, Comblain, et al., 2005; Durbin et al., 2017). Interestingly, although there are relatively few studies, the majority of SRE studies addressing the effect of emotion suggest that the SRE is of equivalent size for neutral and emotional information (Fossati et al., 2004; Gutchess, Kensinger, Yoon, et al., 2007; Pauly et al., 2013; Yang et al., 2012).

In this thesis, diverse emotional effects were found across experiments even though very similar procedures and designs were used. Two of the five experiments (Experiments 3 and 5) showed no effect of emotional valence on memory, while Experiment 1 showed better overall memory for neutral as compared to positive and negative items, regardless of whether the items were processed in relation to the self or others. Experiment 3 showed better overall memory for positive items as compared to neutral and negative items, while Experiment 4 showed better overall memory for negative as compared to positive and neutral items. There thus seems to be little consistency across experiments. However, it is worth noting that the diverse findings in the thesis are not exceptional. In the literature, there have also been reports of diverse effects of emotional valence (e.g., Adelman & Estes, 2013; Bisby & Burgess, 2014; Finn, Roediger, & Rosenzweig, 2012; Leblond et al., 2016; MacKenzie et al., 2015; Sharot et al., 2004). The diverse findings might be due to emotion affecting human cognition in multiple ways. For example, emotional stimuli are often more arousing than neutral stimuli, and the memory benefits seen for emotional items may in fact reflect the benefit to memory of high arousal (Kensinger, 2009; Kensinger & Schacter, 2008; Mather & Sutherland, 2009; Phelps, 2006). In addition, emotional valence may affect the placement of a response criterion (Adelman & Estes, 2013). It has been shown that negative emotions trigger a more liberal response criterion, where participants are more likely to answer ‘yes’ to the question of whether an item is old. This results in higher hit rates and false alarm rates for negative items (Adelman & Estes, 2013). At this point, it is not clear how to explain the diverse effects of emotion in the literature and this thesis. More studies focusing on the effect of emotion are necessary to address this issue. One possibility is through experiments manipulating liberal and conservative placements of criteria among neutral and emotional stimuli, to address whether an interaction between criterion placements and emotion is present.

Across the five experiments reported in this thesis, none showed significant interactions between the size of the SRE and emotional valence. In particular, the greater SRE previously reported for positive items (Durbin et al., 2017; Zhang et al., 2013) was not found here. The current data are thus not compatible with the idea that participants encode positive items better than negative items in relation to the self with the view of keeping a positive self-image (D'Argembeau, Comblain, et al., 2005; Durbin et al., 2017) and neglect negative items (Green et al., 2005; Pinter et al., 2011). Nevertheless, participants rated themselves as more consistent with positive items during encoding. This finding is consistent with the idea that participants prefer to keep a positive self-image (D'Argembeau, Comblain, et al., 2005; Durbin et al., 2017).

## 8.6 Limitations and suggestions for future research

This thesis addressed the role of the self in episodic memory. In this section, I will discuss the limitations of the experiments that were executed and propose possible suggestions for future research.

In this thesis, the effect of closeness to others was addressed with encoding conditions that manipulated levels of closeness while keeping familiarity with others constant. The subjective closeness of a close other for each participant was measured with a bespoke questionnaire. The closeness to a distant other, on the other hand, was based on previous findings suggesting that lower levels of emotional experiences are elicited by fictional characters (LaMarre & Landreville, 2009; Sperduti et al., 2016). The subjective closeness to the fictional character was not measured directly. This design provided an adequate contrast but may have failed to reflect variations of closeness to each fictional character to each participant. It is thus not clear whether closeness to distant others may have varied between participants and contributed to the results. Future experiments can resolve this concern by acquiring subjective closeness ratings for the distant other employed in an experiment. Alternatively, any effect of closeness on episodic memory can be investigated by creating different levels of closeness to strangers in the laboratory setting. Aron et al. (1997) provided a closeness-generating procedure to create a temporary feeling of closeness to others in lab contexts. In lab sessions, an individual may carry out self-disclosure and relationship-building tasks with another participant in a pair. It has been shown that this procedure is effective in increasing the feeling of closeness to others. This approach might be useful for future research to investigate the role of subjective closeness in episodic memory as it provides the potential to create relationships with different levels of temporary closeness in real life.

This thesis was designed to address whether the self or closeness to others is the key factor underlying the SRE. The levels of familiarity were controlled across conditions but not manipulated explicitly. Subsequent research can address this issue by varying the levels of familiarity to others. With subjective familiarity ratings from the participants to multiple others, it is possible to assign conditions with different levels of familiarity as encoding targets to investigate the effect of familiarity on episodic memory. Familiarity with, and closeness to, others have been two factors related to the SRE and yet not fully investigated in the literature (Klein, 2012; Symons & Johnson, 1997). Although the findings of the thesis provide some insights into the effect of closeness to the SRE, a fully factorial design of the two factors can be useful to fully understand the reasons why memory is better for information relating to the self. This allows the interaction between familiarity and closeness to others on episodic memory to be revealed.

The brain activities in this thesis were mostly compared to recollected-related and familiarity-related effects in the literature (Friedman & Johnson, 2000; Hanslmayr et al., 2016; Paller & Wagner, 2002; Rugg & Curran, 2007; Vilberg & Rugg, 2007). During encoding, items that were judged as old based on familiarity were combined with items that were missed to increase the signal-to-noise ratio of the brain signals. Similarly, during retrieval, old/new effects in ERPs and oscillations were based on recollected old and correctly rejected new items. These manipulations were needed to avoid lengthy experimental sessions while maintaining sufficient signal-to-noise ratios for the comparisons of interests. This approach allowed sufficient trial numbers to investigate effects related to recollection. However, this approach comes at the expense of insufficient trial numbers to consider effects of familiarity-based recognition. This issue thus remains a fruitful area for future investigation. It has been shown that insufficient power or sample size can potentially lead to both false-positive and false-negative results (Button et al., 2013). Across the five experiments of the thesis, the numbers of samples were kept comparable to relevant studies in the literature. Nevertheless, it is possible that the small size of effects may not be properly detected by the complex analysis of the thesis, leaving a risk of false-negative results. Future studies can address this potential issue by considering a proper power analysis as part of the experimental design, given that it has been suggested that the statistical power of neuroscience studies was generally low (Button et al., 2013).

In addition to the oscillatory power changes reported in the thesis, additional analysis could also be done to investigate the role of the self in episodic memory. For example, cross frequency coupling has been shown to play an important role in memory formation (Hanslmayr et al., 2016; Hanslmayr & Staudigl, 2014). Theta-gamma coupling in the hippocampus has been directly linked to information binding during memory encoding (B. Lega, Burke, Jacobs, & Kahana, 2016; Staudigl & Hanslmayr, 2013; Tort, Komorowski, Manns, Kopell, & Eichenbaum, 2009). It has also been shown that theta and gamma oscillations in the hippocampus are necessary for binding episodes. On the other hand, cortical alpha and beta oscillations seem important for representing the episodes that are encoded (Hanslmayr et al., 2016). These findings open up new possibilities for researchers to address how the self interacts with episodic memory. Moreover, more general issues of oscillatory activities await future investigation. For example, it is not clear how oscillations during different stages of memory process affect memory performance, for example pre- and post-stimulus activity. How do these neural activities act together to create a holistic construct in episodic memory? Are the theta oscillations observed during pre-stimulus intervals the same as those during post-stimulus encoding or retrieval? Although there is evidence the power changes in similar frequency bands during the encoding and retrieval of episodic memories reflect memory reinstatement (e.g., Hanslmayr et al., 2016; Staudigl et al., 2015), more evidence is needed to understand how the brain supports the effective encoding and retrieval of information about the self.

## 8.7 Conclusions

The self has been shown to be an effective way to encode information and to be able to elicit better memory performance compared to other types of encoding tasks and people (the self-referenced effect, SRE). However, the neural and cognitive mechanisms underlying the SRE are not fully understood. Some researchers suggest that the self is a specialised body that can bind information in a special way (e.g., Sui, 2016; Sui & Humphreys, 2015; Turk et al., 2011), while others argue that closeness to others is a key factor that underlies the SRE (Klein, 2012; Symons & Johnson, 1997).

The current thesis addressed these issues with behavioural and EEG experiments. The results suggested that (1) information pertaining to the self is always remembered better than information pertaining to others, regardless the levels of closeness; (2) the superior processing of information pertaining to the self affects both encoding and retrieval processes; (3) ERPs and oscillatory activities related to the self and a close other are dissociable both temporally and spatially during memory encoding and retrieval, and (4) information processing of the self is context-dependent. Altogether, the thesis suggests that the self a psychologically and anatomically specialised affiliation that can affect information processing over time.

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# Appendix A: Material lists

## Experiment 1, 2 and 3 (behavioural)

helpless
glum
witless
scary
sickly
snide
repressed
ruthless
boring
stupid
foolish
lazy
frightful
frail
moody
fussy
needy
messy
snooty
tasteless
timid
hapless
shameless
touchy
tough
solemn
childish
docile
posh
curt
idle
oblique
fickle
wacky
gutsy
candid
feeble
sluggish
sleepy
stable
sedate
genteel
prudent
cheeky
mild
daring
prompt
polite
serene
tasteful
upbeat
helpful
earnest
frosty
eager
patient
proud
lively
unique
sunny
tidy
gallant
precious
courteous
noble
carefree
unkind
heartless
irate
confused
severe
devious
tedious
fake
sullen
spineless
gloomy
weary
flaky
mundane
dumb
lonely
bossy
nasty
crabby
uptight
rambling
strict
stern
fierce
transient
stoic
maudlin
wooden
subtle
fearless
picky
absent
naive
loony
flashy
nutty
mature
gritty
shabby
huffy
stony
meek
random
stylish
precise
humble
classy
keen
cheery
grateful
blissful
refined
arty
profound
willing
clever
brilliant
sweet
perky
astute
harmless
mellow
wishful
jolly
funny
cheerful
rude
mean
spiteful
pompous
dull
prickly
uncouth
shallow
depressed
creepy
selfish
rigid
restless
crude
wary
hostile
furious
pushy
mournful
envious
smug
listless
gutless
shrewd
daft
vacant
passive
weird
lenient
inept
petty
coarse
fragile
trendy
plucky
distinct
sneaky
hasty
chatty
aloof
pithy
brazen
lucid
intense
tame
valiant
goofy
calm
secure
witty
fancy
peaceful
thorough
nifty
silly
youthful
sincere
loyal
hopeful
joyful
cultured
smooth
charming
graceful
lucky
smart
grumpy
awkward
cranky
rash
senseless
harsh
bitter
stingy
drab
callous
reckless
noisy
sloppy
jaded
slack
jealous
fearful
nosy
shifty
testy
stuffy
sleazy
bland
clumsy
brash
blunt
placid
droll
bashful
crafty
forlorn
manic
potty
discreet
casual
punctual
gruff
vague
sappy
mushy
edgy
bonkers
suave
cautious
righteous
decent
modest
selfless
tranquil
merry
wise
naughty
vivid
gifted
mindful
pleasant
truthful
playful
honest
tactful
bold
virtuous
neat
gracious
brave
awesome

## Experiment 4 and 5 (EEG)

helpless
grim
angry
boring
fussy
grumpy
glum
stupid
needy
awkward
weak
witless
foolish
messy
cranky
scary
lazy
snooty
rash
sickly
crude
tasteless
senseless
snide
grouchy
timid
harsh
repressed
clueless
frail
hapless
bitter
ruthless
moody
stubborn
risky
dopey
seedy
feeble
bland
shameless
prissy
curt
sluggish
clumsy
skittish
touchy
idle
sleepy
brash
tough
oblique
thick
blunt
solemn

strange
fickle
sedate
placid
childish
bonkers
discreet
genteel
droll
sassy
sharp
prudent
formal
private
bashful
posh
candid
cheeky
crafty
serious
mild
earnest
chummy
righteous
daring
frosty
tidy
decent
prompt
eager
gallant
modest
polite
patient
precious
bright
tasteful
serene
proud
courteous
tranquil
selfless
lively
fair
noble
simple
merry
pleasant
unique
carefree
wise
helpful
warm
lovely
kind

friendly
sunny
dumb
stingy
unkind
fake
vicious
lonely
drab
heartless
scared
sullen
bossy
callous
irate
spineless
nasty
reckless
confused
gloomy
uptight
crabby
noisy
severe
weary
worried
sloppy
devious
flaky
rambling
jaded
tedious
mundane
strict
tearful
shady
crass
slack
surly
stern
picky
gritty
forlorn
slow
fierce
absent
shabby
manic
transient
naive
huffy
potty
stoic
loony
stony

concerned
loopy
distant
maudlin
flashy
meek
plain
silent
cheap
wooden
nutty
random
deep
gutsy
subtle
reserved
proper
direct
civil
different
wild
mature
perky
naughty
precise
refined
astute
vivid
humble
arty
harmless
gifted
classy
profound
mellow
mindful
keen
strong
cool
willing
wishful
sincere
graceful
charming
upbeat
cheery
clever
gentle
jolly
truthful
special
grateful
brilliant
funny
playful

blissful
sweet
cheerful
honest
rude
greedy
vengeful
depressed
hostile
jealous
mean
scornful
creepy
furious
fearful
spiteful
frightful
weepy
pushy
nosy
pompous
selfish
vulgar
mournful
shifty
dull
rigid
envious
testy
nervous
prickly
restless
smug
rough
stuffy
uncouth
anxious
listless
sleazy
shallow
wary
sneaky
gruff
gutless
inept
hasty
vague
shrewd
petty
chatty
sappy
daft
coarse
aloof
mushy

vacant
fragile
pithy
edgy
passive
trendy
brazen
dark
weird
plucky
stable
lucid
suave
lenient
distinct
intense
stylish
punctual
docile
fearless
casual
cautious
wacky
quick
tame
open
thorough
cultured
normal
tactful
valiant
nifty
careful
smooth
quiet
curious
bold
goofy
silly
sane
moral
virtuous
calm
youthful
nice
neat
secure
clean
perfect
gracious
witty
loyal
lucky
brave
fancy
hopeful
smart
awesome
peaceful
joyful
happy

### Practice (behavioural and EEG)

frightened
clingy
careless
thoughtless
headstrong
crazy
public
brainy
forthright
inspired
thoughtful
good

## Appendix B: Closeness and familiarity questionnaire

**Study code:**

**Participant code:**

**Date:**

Please write down the names of six people you are familiar with in the boxes below. These should be people you know well. You only need to write down their first names, not their surnames. We want you to write down the names of the six people in the order of how close of an emotional bond you feel you have with each of them. In the first box, write down the names of the two people you feel you have the **closest** emotional bond with. In the second box, write down the names of the two people you feel **next closest** to. Finally, write down the names of the two people you feel **least close** to out of the six you chose. Write down the names that first come to mind. Please be assured that the information you provide will be kept confidential.

| **Closest (out of the 6)** | **Less close (out of the 6)** | **Least close (out of the 6)** |
|---|---|---|
| 1. ____________________<br>2. ____________________ | 3. ____________________<br>4. ____________________ | 5. ____________________<br>6. ____________________ |

I would now like you to provide more details about the people you listed above. Please answer the five questions below by writing a number between 1 and 10 for each of the six people you chose.

| **Questions** | **Person 1** | **Person 2** | **Person 3** | **Person 4** | **Person 5** | **Person 6** |
|---|---|---|---|---|---|---|
| **1. How well do you know the person?** (1 = not well at all, almost like a stranger, 10 = very well, almost like myself) | | | | | | |
| **2. How well do you think the person knows you?** (1 = not well at all, almost like a stranger, 10 = very well, almost like myself) | | | | | | |
| **3. How close do you feel you are to the person?** (1 = not close at all, almost like a stranger, 10 = very close, almost like myself) | | | | | | |
| **4. How close does the person feel to you?** (1 = not close at all, almost like a stranger, 10 = very close, almost like myself) | | | | | | |
| **5. What is the relationship between you and the person?** | | | | | | |

Thank you very much!